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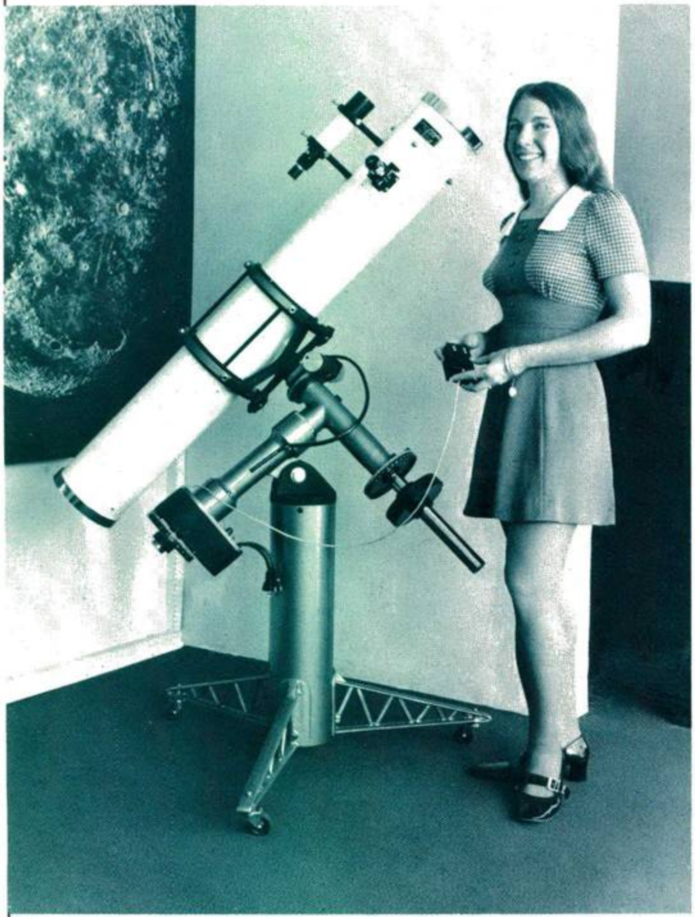

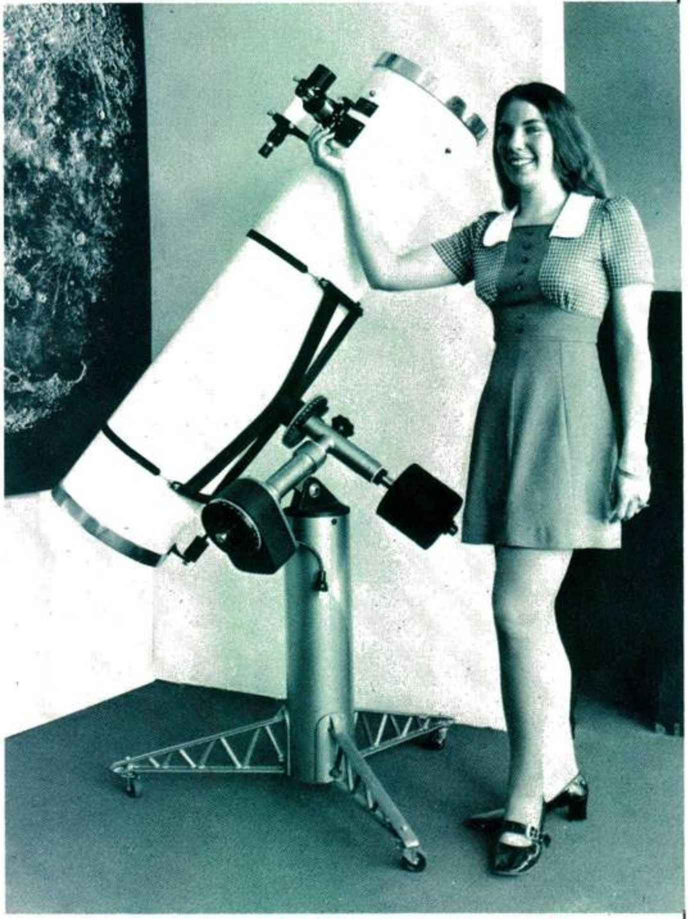

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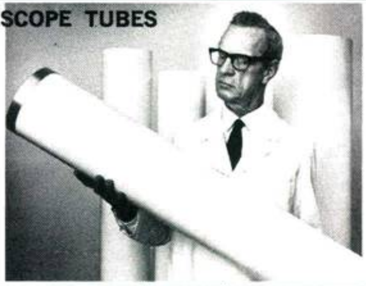

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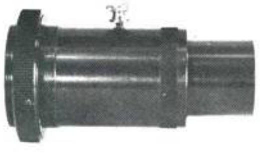

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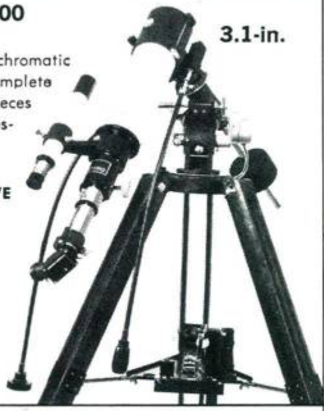

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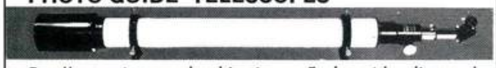

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PUBLISHER'S MEMO

Just a short note this month to let you know the status of several loose ends.

At the time this memo is being written, we've received about 250 requests for the proposed 8-1/2 x 11 inch photo sets mentioned in my February 1975 Publisher's Memo. I repeat what I said in that memo: To make it economically feasible to publish these photographs, we must find at least 500 readers who would be willing to buy them at $2 for a set of eight. So although we're halfway home, keep those cards and letters coming in, folks — and **do not** send payment until we announce that the prints have indeed been published.

Keep your eyes "peeled" for next month's Publisher's Memo. By that time the survey from the December 1974 issue will be tabulated and we'll let you know some of the results.

In February, ASTRONOMY conducted another direct mail campaign in order to boost circulation. By the May issue we will have added between 6,000 and 8,000 new subscribers making our circulation 45,000 to 47,000 strong.

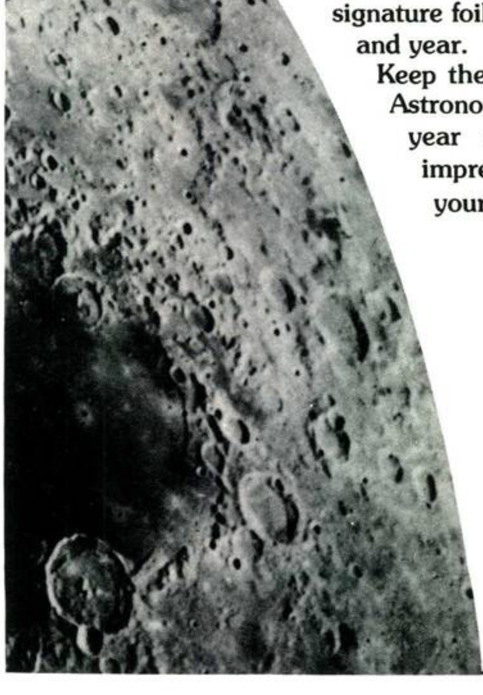
On a personal note, your near unqualified enthusiasm toward ASTRONOMY must mean we're doing something right. All I can say is that I'm warmly proud to be able to publish a magazine that has such an involved readership.

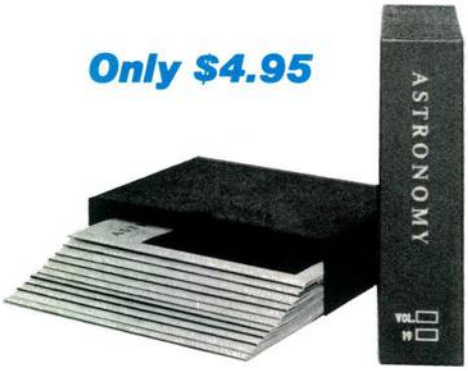
By the way, we hope you like ASTRONOMY's new Volume Files advertised below.

Sincerely,

Stephen A. Walther

Stephen A. Walther
Publisher





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The World's Most Beautiful Astronomy Magazine

April 1975 Vol. 3, No. 4

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Cover

U.S. Naval Observatory Photograph

Sixty billion stars comprise the Whirlpool galaxy, a small version of the Milky Way galaxy. Known as M-51, this 40,000 light-year wide spiral is 12 million light-years distant. The companion galaxy that seems to be an extension of a spiral arm is known as NGC-5195. Many spirals have smaller satellite galaxies such as this. The motions of galaxies away from us has sparked continuing speculation on the origin and destiny of the universe as described in the feature article this month. The telescopic appearance of this galaxy is described in Star Dome. The photo was taken through a 39 inch telescope on High Speed Ektachrome using a cold emulsion camera.

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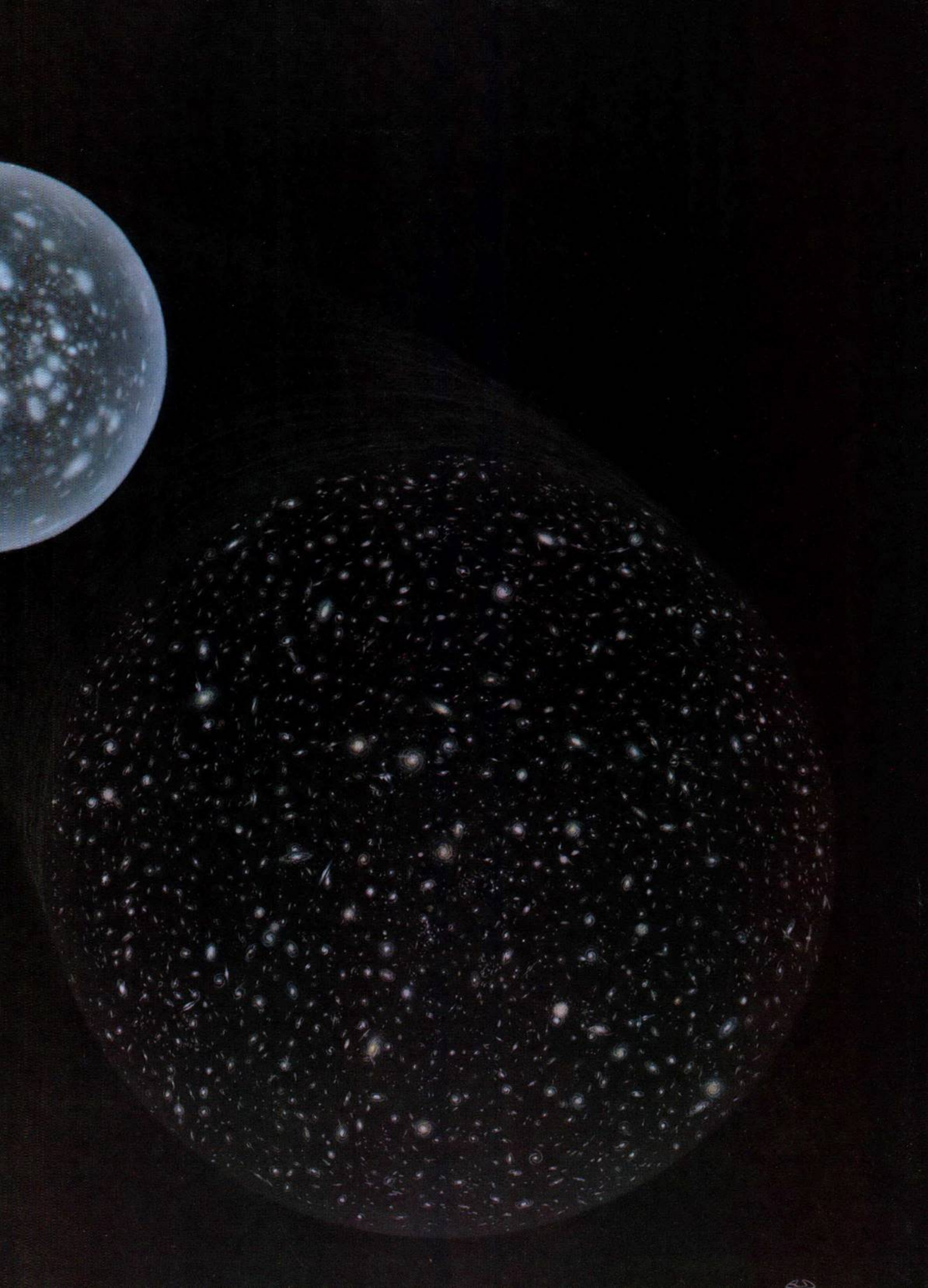
The Cosmic Bomb

by
Donald Goldsmith

Four stages in the universe's evolution are depicted above. Roughly 15 billion years ago an explosion instantaneously created the universe. For perhaps one million years, the Radiation era followed as a fireball of intense energy continued expanding. Next, the Galaxian era saw the universe cool, allowing its thin distribution of hydrogen to begin slowly condensing into clusters of galaxies. In the Present era, galaxies dominate as matter continues flying outward from the primordial big bang. What will the universe's future evolution look like? This article explores some possibilities.

Artwork by Adolf Schaller

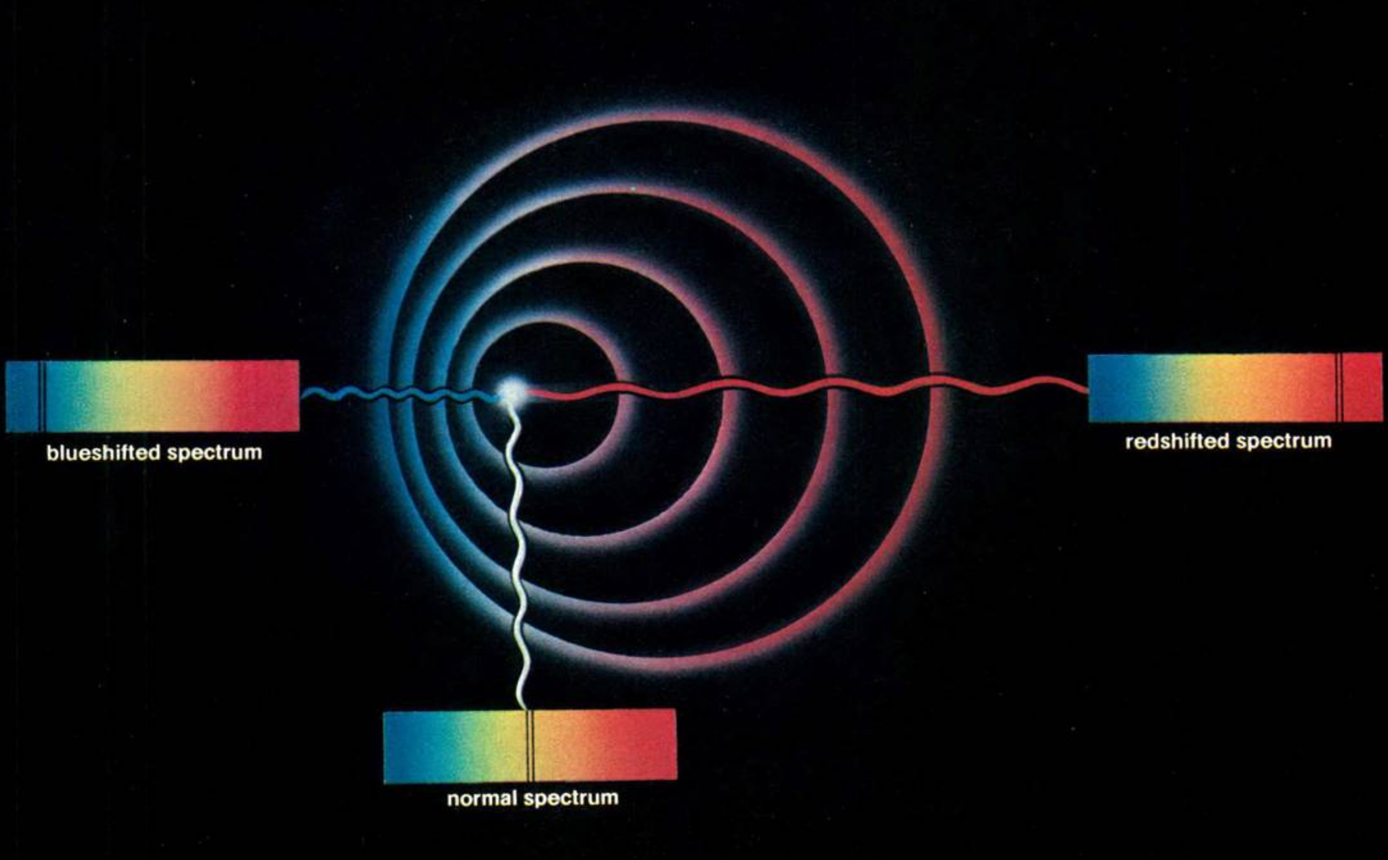


Few things in nature appear more static, tranquil and eternal than the frozen star patterns of the nighttime sky. But all that our eyes and instruments encompass may really be only glowing debris flung outward from a colossal explosion billions of years ago. It assaults common sense to imagine that everything in existence was born out of a sizzling fireball. Yet, that seems to be our heritage.

The first clues that the universe had a definite beginning came before astronomers even realized that galaxies existed beyond our own Milky Way. Early in this century galaxies were considered only glowing clouds of material or nebulae floating *within* our island of stars. But one thing about them was strange: Unlike other interstellar clouds, the light from these "spiral nebulae" was significantly *redshifted.*

Astronomers interpret the shifting of an object's light into the red end of the visible spectrum as indicating that it is receding from us. While hurtling away the object "pulls" its radiating light along with it, stretching its wavelength into lower frequencies. If the object approaches us instead, energy gets compressed into the shorter, bluer wavelengths. We experience this phenomenon almost daily. As a police car or ambulance races away, we hear an abrupt drop in the siren's pitch or frequency as the vehicle's speed stretches out sound waves.

The odd behavior of the spiral nebulae told astronomers that something was very wrong with concepts about the universe's structure. There was



no reason that some objects within the galaxy should *all* be receding from us. Other nebulae and stars were equally split between those drifting toward and those drifting away from Earth. More importantly, the spiral nebulae were all moving away much faster than any other objects.

In the 1920s astronomer Edwin Hubble cracked the puzzle by discovering that spiral nebulae were really vast cities of stars — galaxies — at great distances *beyond* the Milky Way. He abruptly shrank the Milky Way to one insignificant galaxy in a universe apparently teeming with other galaxies. And if that wasn't shock enough, it also meant that the entire universe was flying apart. Outside of our local cluster of 17 galaxies, everything else in creation was stampeding toward the dark, unknown fringes of space.

By comparing galaxies' distances to their velocities (or redshifts), Hubble found a surprising proportion between speed and distance. A galaxy twice as far away from us will be traveling twice as fast as the nearer neighbor. For example, the Coma cluster of galaxies — about 400 million light-years (one light-year equals 5.9 trillion miles) away — is receding from us at 4,400 miles per second. At one billion light-years distant, the largest galaxy cluster in the constellation Corona Borealis has a recession velocity of 13,400 miles per second.

Each galaxy or cluster of galaxies does have some random velocity of its own — no more than a few hundred miles per second — which overlies the basic proportionality between the galaxy's distance and speed from us. However, the amounts of these random velocities are far less than the recession velocities of all but the nearest galaxies.

Hubble's law describes the motions of distant galaxies as they appear to us: all receding, at speeds proportional to their distances from us. Why, then, don't astronomers conclude that we are at the center of the universe's expansion? Basically, because they have learned a lesson from the past.

Copernicus pushed Earth from the solar system's center. Harlow Shapley moved the solar system from the Milky Way's core to its outer disk. And Hubble reduced the Milky Way to a commonplace galaxy. After centuries of dethroning man from the center of creation, astronomers have formally devised the so-called *principle of mediocrity,* sometimes called the *cosmological principle.* It simply says we have no reason to believe that the

The Doppler effect explains that light from a radiating object approaching you will be compressed into shorter wavelengths, or the blue end of the spectrum. Conversely, if an object is receding from you its energy will be stretched into longer wavelengths, or the spectrum's red end. Astronomers note such motion by the displacement of absorption lines within an object's spectrum. The "normal" spectrum, as it would appear to an observer standing relatively stationary to the object, is seen at the bottom of the diagram.

Artwork by Victor Costanzo

Hale Observatories Photograph

A portion of the cluster of galaxies in the constellation Hercules is estimated to be 470 million light-years beyond Earth. The entire cluster seems to be increasing its distance from us by 6,700 miles every second. As more than 100 galaxies slowly drift within the cluster, their mutual pull on each other gravitationally binds the Hercules cluster together. Astronomers are trying to learn if, on a much larger scale, the combined gravity of all the universe's galaxy clusters will similarly keep it bound within a finite volume.

Milky Way occupies a special position or plays a special role in the universe. We must assume — unless proven otherwise — that on a galactic scale, we observe the same scene as anyone else in the cosmos.

By applying this principle to distant galaxies we conclude that all observers — in all galaxies — view distant galaxies receding from them with speeds proportional to the galaxies' distances *from them.* All of the universe must then be expanding, everywhere.

Imagine a giant graduation ceremony on a football field, with galaxies as the audience's chairs spaced (for our purposes) three feet apart in straight rows and columns. In this model, the universal expansion means that in one minute, the chairs will each be six feet from their nearest neighbors, and in two minutes move to nine feet apart. Each chair drifts away from every other chair, with a speed proportional to the distance between the two chairs. Extending vertical rows of chairs far above and below each chair on the field completes our model of an expanding universe. Everyone sees everyone else moving away — exactly what we see from our galaxy.

How can this happen? It seems weird to conceive of the entire universe expanding (into what?) since we are — immutably — inside the universe, and cannot hope to imagine how it would look from "outside". The universe, by definition, includes everything. There is no outside.

But we can use our imagination for looking into the past by mentally rewinding the universe's expansion like running a movie backwards. Yesterday all the galaxy clusters must have been infinitesimally (at least on cosmic dimensions) closer to each other; a year ago, slightly more. According to the latest measurements of the universal expansion, the average distance between galaxy clusters was 1/2 its present value about eight billion years ago. At that time, the distance between our own Milky Way and the Coma cluster of galaxies was 200 million light-years instead of the present distance of 400 million light-years. Looking further back into history, we can see that there must have been a time when the average distance between galaxies grew increasingly smaller until everything was crammed into an unimaginably tiny volume. This implies that some spectacular event must have launched the universe on its seemingly timeless journey.

Many cosmologists today believe that a fantastic explosion (nicknamed the "big bang") did the trick. Although no laboratory on Earth can re-create the extreme physical conditions that had to accompany this primordial trauma, theoretical models have produced the following genesis:

In an inky blackness of absolute nothingness floats a superdense (perhaps 200 thousand million tons per cubic inch), superhot (100 billion billion billion degrees) "cosmic egg". Slightly less than the diameter of Earth's orbit it carries the universe's total mass. Within its boundaries a seething caldron of elementary particles (protons, electrons, neutrons, etc.) mix together in a roaring mass of high speed collisions. Each impact generates great quantities of photons or "packets" of electromagnetic energy (radio, microwave, light, ultraviolet, X-ray, gamma ray). Instantaneously, the egg disintegrates like a bursting dam as radiation floods the surrounding black void.

Creation plus 1/1000 of a second: The expanding fireball's energy begins annihilating even the lighter elementary particles. Within 10 seconds, temperature cools to one billion degrees and density plunges toward 36 pounds per cubic inch — dramatically reducing the number of collisions between particles.

For perhaps the following 300,000 years, matter tenuously survives in an expanding sea of radiation. Electrons and protons combining into atoms of hydrogen risk being torn apart by any impinging photon "bullet". But as the universe spreads out, such collisions grow increasingly rare.

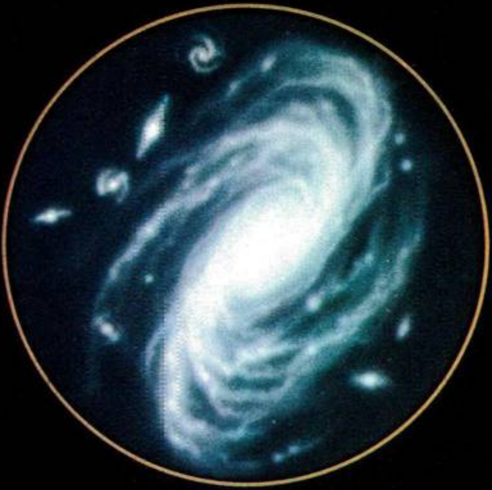
A more subtle phenomenon is also helping early atoms' longevity. As the universe expands, the destructive strength of the ever-receding sea of fireball photons continues diminishing. The so-called *Doppler effect* explains this phenomenon. It basically says that if a source of radiation moves away from an observer (or an observer away from the source), he will notice a drop in its frequency. How much frequency shifts depends on how fast the source is receding.

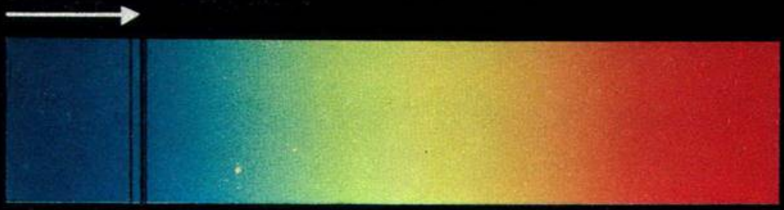
Frequency indicates the amount of energy radiation carries. High frequency gamma rays easily penetrate wood and plaster; ultraviolet rays (the next region of the spectrum above light) cause sunburn in humans. Low frequency infrared and radio waves are relatively harmless.

Earlier we used the example of a departing ambulance's siren to explain how the Doppler effect produces the redshift of light from receding galaxies. Just as more distant galaxies have increasingly attenuated light, the farther the expanding universe carries fireball radiation the lower its energy falls. About 300,000 years after the big bang, this radiation shifted into lower frequencies that were harmless to matter. This critical watershed in the universe's evolution is called the time of decoupling; matter was then free from interference with most primordial photons.

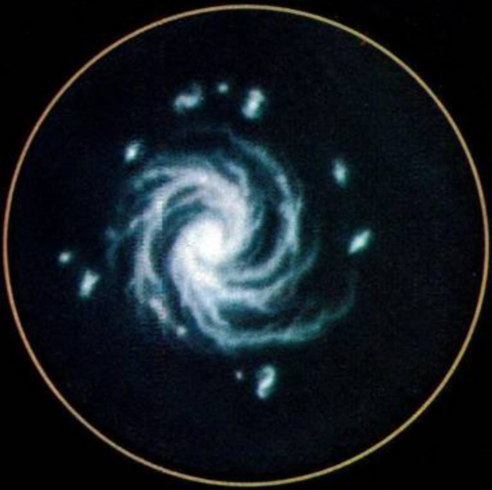
Comparing distances and redshifts of galaxies reveals that the farther a galaxy is the faster it travels away from us. The redshift phenomenon serves as an intergalactic speedometer; the farther the absorption lines are shifted into the red end of the spectrum, the greater an object's speed of recession. Galaxies' speeds also increase proportionally to distance. A galaxy five times farther than another will be receding five times as fast. This evidence strongly suggests that the universe is expanding in all directions.

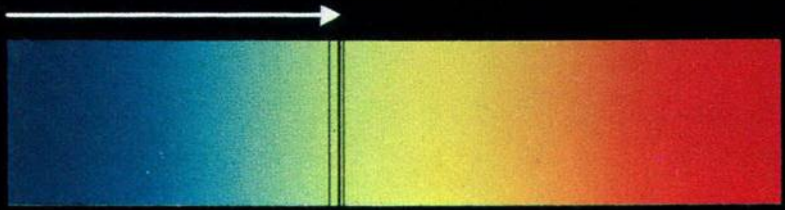
Artwork by Victor Costanzo



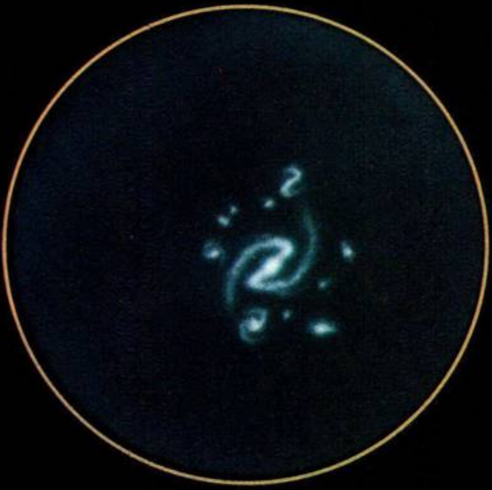


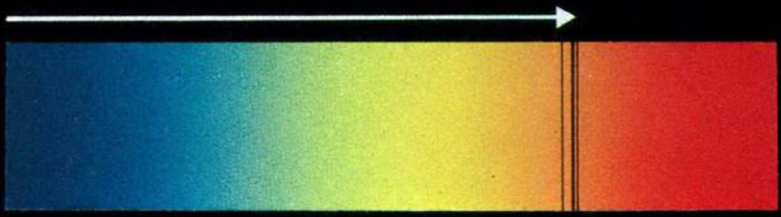
Virgo cluster
distance: 50 million light-years
receding at: 750 miles per second



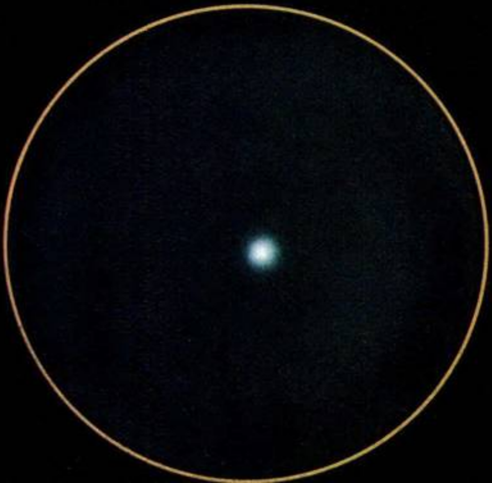


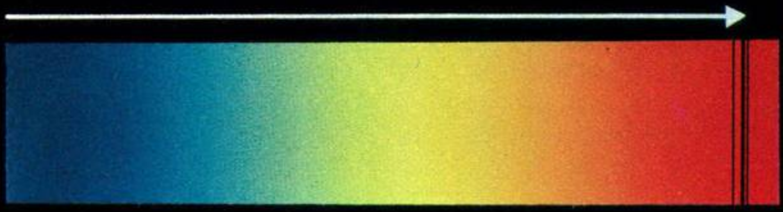
Ursa Major cluster
distance: 650 million light-years
receding at: 9,300 miles per second



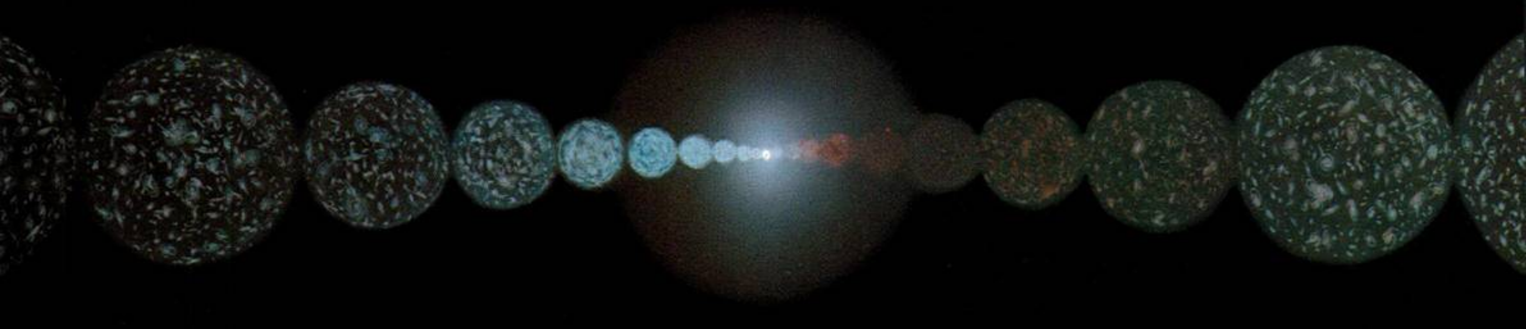


Corona Borealis cluster
distance: 950 million light-years
receding at: 13,400 miles per second





Bootes cluster
distance: 1.7 billion light-years
receding at: 24,000 miles per second



Creation plus one million years: Once a feeble by-product of the big bang, matter now takes domain over energy. Radiation pressure and shock waves from the fireball begin making the cosmos lumpy. Huge cells of hydrogen thicken and slowly condense. Massive eddy currents collapse into black holes (points of intense gravitation that trap matter and energy forever) and lightweight currents smooth out with time. Still other regions tediously evolve toward clusters of galaxies.

Galaxies require a painstakingly long two to four billion years to contract out of a universe now having a low enough density to pass for an almost perfect vacuum in any Earthly lab. Eventually within each galaxy, gravity squeezes billions of tiny hydrogen droplets into individual stars. Several billion years after the big bang's brief radiance, light from myriad suns floods into the universe. Nuclear fusion fires within each star manufacture all the elements heavier than helium. Explosive deaths among the stars pump this enriched matter back into the galaxy. These raw materials end up being drawn into the construction of new suns, planets — and life.

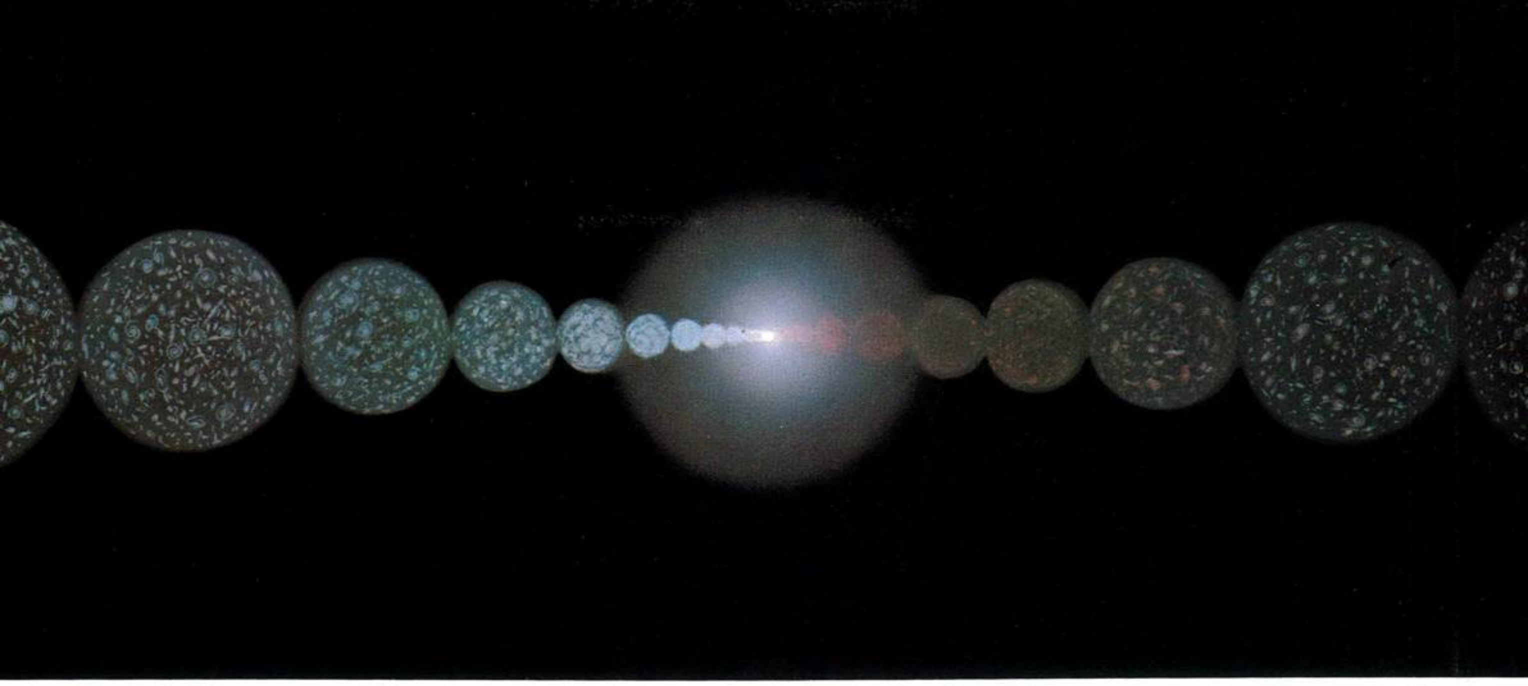
This violently dynamic portrait of the universe according to the big bang theory has not gone unchallenged. In the late 1940s and early 1950s, Sir Fred Hoyle and other astronomers opposed to this jack-in-the-box kind of reality offered the rival "steady state" hypothesis. They described a universe eternal and stable — one that would appear identical to all observers at any point in time. What about the runaway galaxies? Like an overflowing sink, new matter continuously pumped in would forever shove older galaxies toward infinity. Fresh hydrogen (created out of nothing) could appear at a rate of one atom per year in roughly one billion cubic feet of space (too small for detection by present day instruments). This concept of continuous creation did not seem any more unreasonable than conjuring up a cosmic egg out of oblivion.

In the 1950s both rival theories seemed equally viable from observations at that time. But in 1965, evidence tipped in favor of the big bang when radio engineers accidentally found the ghost of that violent event. While investigating strange radio interference in a satellite communication antenna, they uncovered microwave radiation saturating space from all directions. At that same time Princeton astrophysicist R. H. Dicke was reinvestigating the possibility (first suggested in 1934) that a radio afterglow should still be haunting space if the big bang really occurred.

Incredibly, the radiation was made in the first chaotic minutes of the fireball. During the big bang this energy appeared as light and more powerful (and deadly) frequencies. Because the universe has been expanding ever since then, we are now traveling almost at the speed of light relative to the ancient source of those photons. Once responsible for decoupling, the Doppler effect continues shifting photon frequencies into lower regions of the spectrum. Now at 1/1000 its original wavelength, fireball radiation is found in the microwave region (intermediate between radio waves and infrared waves). Because we detect these photons equally coming from all directions, it demonstrates that the universe has no "center"; instead, the apparent origin of the universe surrounds us. This 15 billion year old cosmic relic from the past provides astronomers with their best evidence yet for the big bang.

Even if we know a primordial explosion began the universe, it leaves unanswered the most nagging question of all: Will the expansion continue forever? If so, then the cosmos is infinite or "open" and galaxy clusters will eternally scatter into deep space.

If the universe is instead finite or "closed", the mutual gravitation of all galaxies should be slowing it down fast enough to brake the expansion.



Artwork by Adolf Schaller

Some cosmologists suggest that the universe oscillates in a chain of expansions and contractions. Each pulsation lasts perhaps tens of billions of years and dies in a superhot explosion as all matter crashes back together. However, the same blast also triggers the birth of a new universe — one possibly having different physical properties from those of its predecessor.

A growing, finite universe might resemble the inflating surface of a polka-dotted balloon. In this model, the dots represent clusters of galaxies. As the balloon expands each dot moves away from all the other dots at speeds proportional to the distance between them. The balloon's surface has only a finite area (which, however, increases as the balloon inflates). In a finite universe, *all* of three-dimensional space is *curved* — in a way analogous to the curvature of the two-dimensional space on the surface of a balloon. There would be no "center" for the expanding universe, just as the surface of an expanding balloon has no center. (The actual center of the expanding balloon lies away from its surface in an extra, third dimension. We believe that space has only three dimensions, and we do not have an extra fourth dimension in which to find the center of the universe's curvature.) If the universe is finite, the curvature of its three-dimensional space means that any journey in a straight line would eventually lead back around the universe and not go on to infinity.

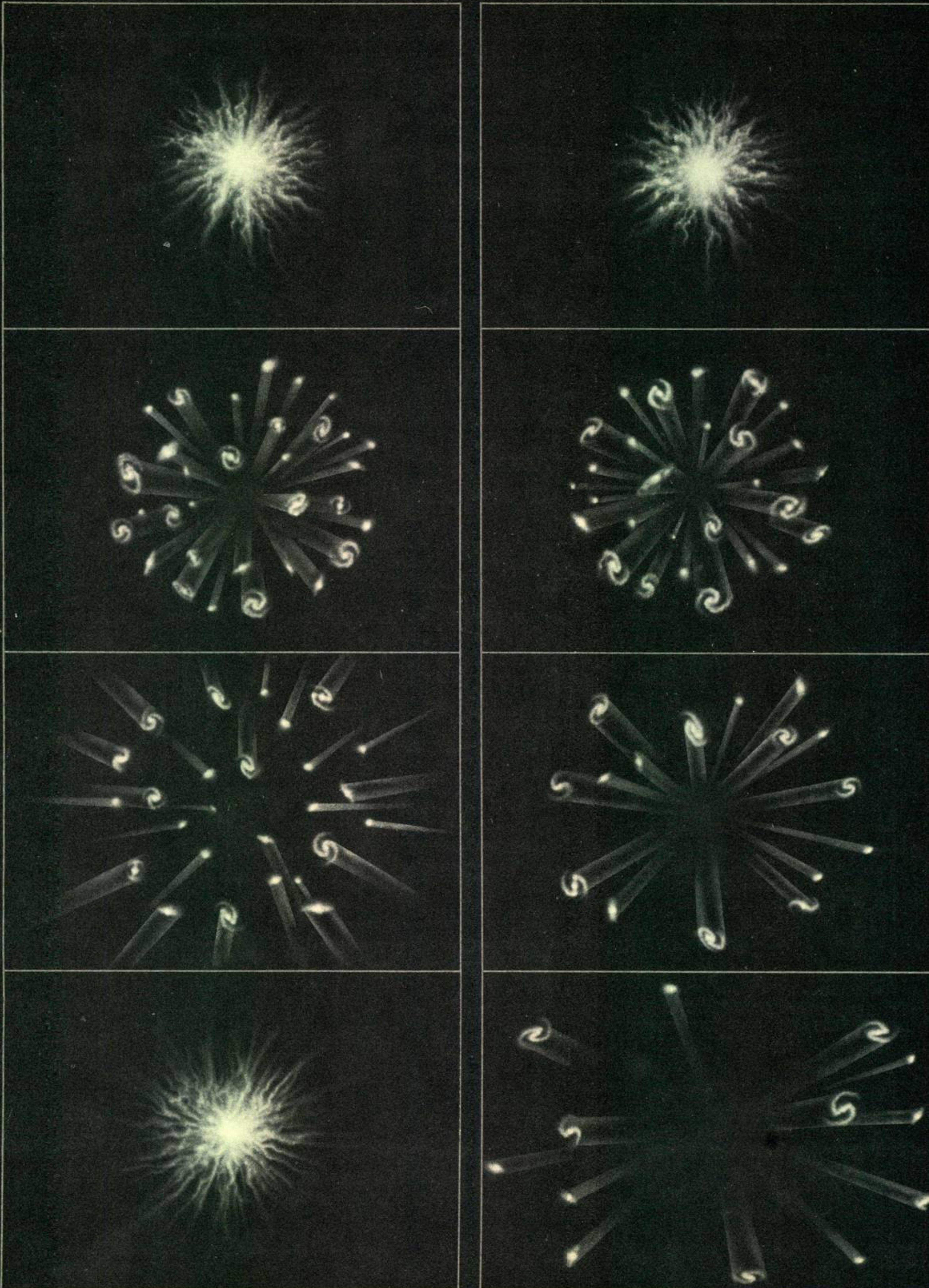
A closed universe would be finite not only in space but also in time. Imagine a point in the distant future when all galaxy clusters simultaneously grind to a halt. For an instant in the universe's long history, everything in creation hangs motionless in space. But a second later the most gentle tug of each galaxy's gravitation upon every other galaxy begins drawing them back toward each other. Like a deflating balloon the universe's volume progressively shrinks. Astronomers of generations following the turnaround startlingly observe "blueshifts" as all external galaxies race headlong toward ultimate collision. The universe dies in a churning fireball — as it once began.

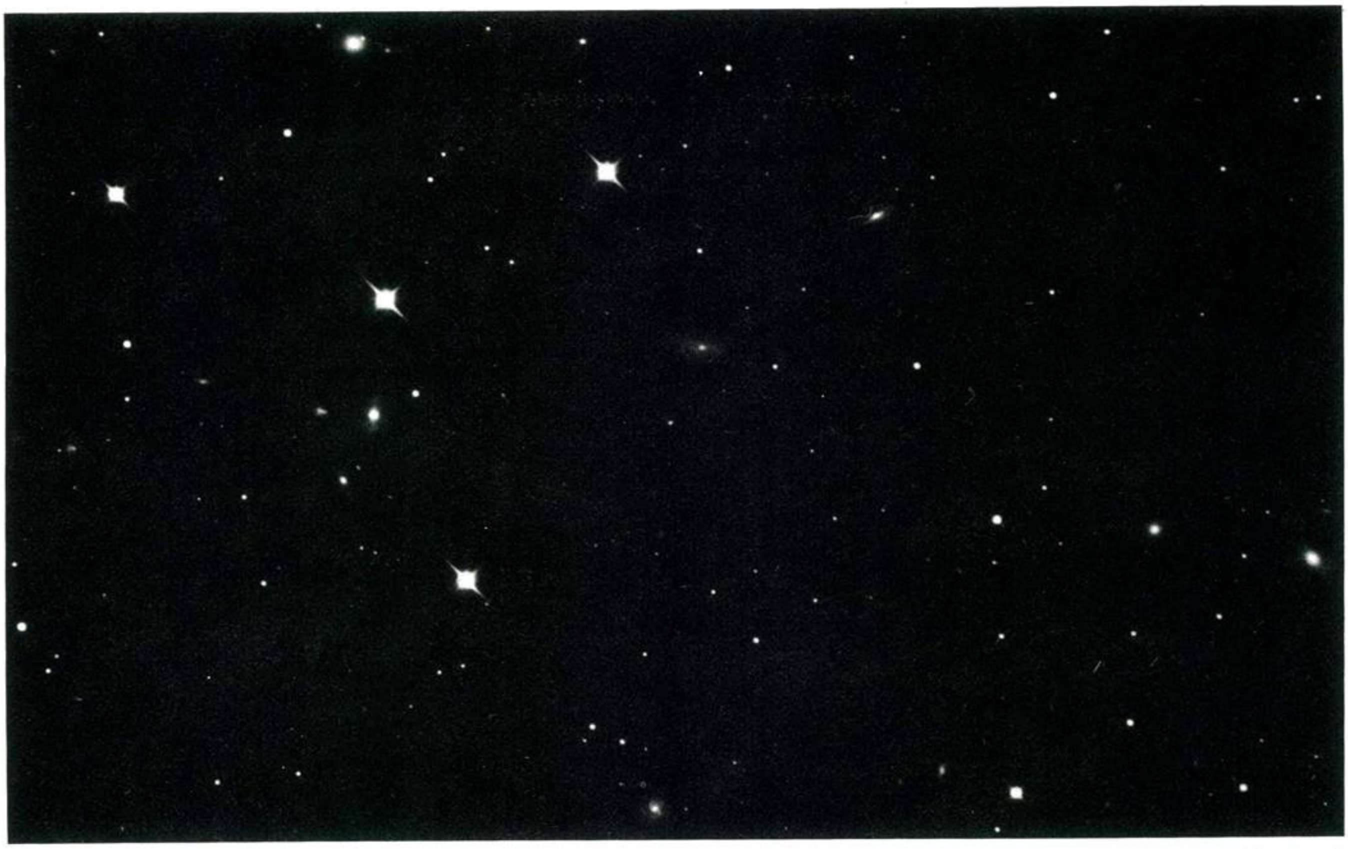
Astronomers are anxiously attacking the puzzle of the universe's destiny on many different fronts. Some are trying to determine if there is enough mass in the cosmos to gravitationally glue it together. Galaxies fall about 10 to 100 times short of having sufficient *visible mass* to do the job. *Invisible* or *missing mass* may be locked up in black holes, halos of dark material around galaxies, burned-out dead galaxies or faint dwarf galaxies. Observations have detected some mass between galaxies but not enough to make it someday contract.

Other astronomers are measuring the amount of deuterium (a heavier form of hydrogen) in space to gauge the universe's mass. On the assumption that deuterium was only made in the first chaotic moments of the big bang, they calculate that a lot of deuterium present today would mean that the cosmic egg was relatively lightweight. If the egg was dense enough to keep the universe closed, most deuterium should have been converted into helium. Present deuterium measurements suggest an open universe.

Another major approach involves learning if the universe is expanding fast enough to be open. By comparing galaxies' distances to their speeds, cosmologists keep refining the value of this expansion rate. However, increasing debate over the validity of yardsticks used for finding speeds and distances keeps astronomers from agreeing on a recession speed. If galaxies grow dimmer over time, as some astronomers suggest, then distance estimates based on luminosity are botched up. And if some unknown phenomenon is stretching the frequency of light from very distant objects, then speed estimates based on redshifts are also misleading.

When quasars were first discovered in the early 1960s cosmologists hoped that these mysterious





Lick Observatory Photograph

Another region of the gigantic Hercules cluster of galaxies (whose densest portion is illustrated on page 9) shows the variety of galaxy types and sizes that comprise the assemblage. Here the galaxies are barely one million light-years apart.

Yet the very existence of galaxy clusters, and the fact that they remain as clusters over vast periods of time, is a fundamental fact that plays a key role in our understanding of the universe.

starlike sources of intense light and radio energy promised important clues about universal expansion. While most galaxy clusters range from tens to hundreds of millions of light-years away, quasars seemingly dwell billions of light-years away, on the horizon of the visible universe. Unlike galaxies, quasars' speeds (redshifts) do not neatly correspond to their distances. For example, the redshift of one quasar indicates that it is traveling away at a much greater speed than others that seem to form a cluster. All cluster members would seem to be at the same distance and therefore should have the same redshift. Such confusing evidence has so far only raised more problems than it has solved.

If the universe turns out gravitationally closed, what — if anything — would follow its crushing collapse? Some cosmologists envision that in the last seconds of existence all matter (consisting mostly of burned-out corpses of myriad stars) jams into an incredibly small space. Densities and temperatures skyrocket; the ultra-concentrated mass becomes unstable. Pow! Instantly energy screams outward in a billowing fireball. Like the mythological Phoenix, a new universe arises from its own ashes.

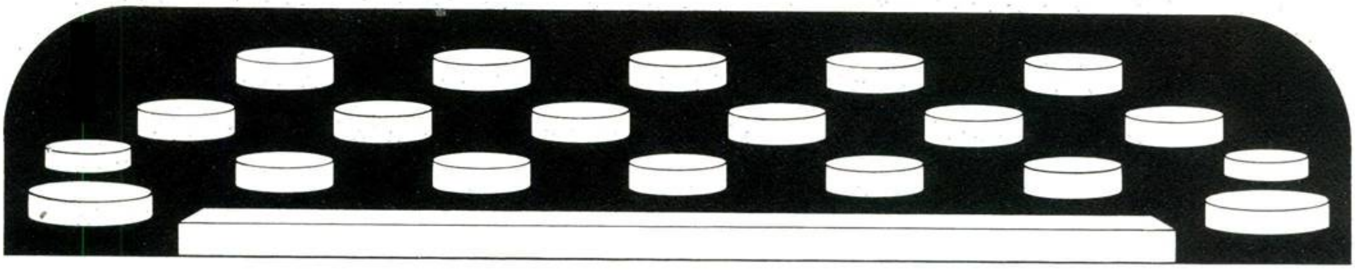
This concept of an *oscillating* universe reduces our cosmos to a humble link in an endless chain of universes. Each universe might last tens of billions of years and perhaps have its own unique set of physical constants — such as the mass and charge of elementary particles, and the velocity of light. Some cosmologists even speculate that only certain universes might have the proper balance of constants for life to exist.

Even when cloaked in the sophistication of today's science and technology, unraveling the secret of creation remains mind boggling. From Stonehenge to Tranquility Base, this profound puzzle continues haunting human consciousness. Now — within a single generation — we may at last learn the ultimate origin and destiny we share with all life in the universe.

A gravitationally closed universe versus a gravitationally open universe is visualized in this rendering. In both models the explosion of a "cosmic egg" begins expansion. Galaxies eventually condense and continue receding from each other — this is how the universe appears today. In the closed or finite universe, mutual gravitation among galaxies is strong enough to halt expansion. They begin contracting toward each other and eventual collision. In the open universe, gravity is too weak to stop the runaway matter and galaxies forever travel toward infinity.

Artwork by Victor Costanzo

Dr. Donald Goldsmith is presently involved in production of several books and films on astronomy in conjunction with Interstellar Media of San Francisco, Calif. He co-authored **From the Black Hole to the Infinite Universe** *(reviewed in the July 1974 issue), and formerly taught astronomy at the State University of New York at Stoney Brook.*



IN FOCUS

Sir / On page 10 of "Black Holes — Gateway or Grave?" you state that Earth would become a black hole when its circumference reaches the approximate size of 2.196 inches. Yet, according to the bottom illustration, you show an escape velocity for a one mile diameter Earth as being greater than the speed of light — the velocity wherein an object becomes a black hole. Are black holes really larger than we thought?

TY BLISS
Pensacola, Fla.

Mr. Bliss / As indicated in the article's text, calculations for a black hole of one Earth mass confirm a 2.196 inch circumference. However, the escape velocity presented in the diagram for a one mile diameter Earth was too high. Escape velocity increases proportionally to the inverse square root of Earth's radius instead of the inverse square of Earth's radius as indicated in the diagram. Proper escape velocities for the diagram are respectively 7, 14, 49 and 437 miles per second. The diagram's data for increases in weight is correct varying in proportion to $1/radius^2$*.*

Sir / I would like to take a couple of minor exceptions to the article by Jack Newton in the July 1974 issue.

I wish that writers would define what is meant by a "small telescope" in terms of aperture. For example, Newton states that the Veil nebula is "virtually impossible to see in small telescopes...", but my eight inch Schmidt-Cassegrain shows it easily — and I am sure that it must also be visible in a six inch as well. I also don't find M-51 deserving of the term "unspectacular", as far as galaxies are concerned. On a dark night, I can do a little spiral arm tracing with my eight inch. In how many galaxies can one see detail in a "small" telescope?

I must frequently remind myself not to assume that I can't see an object or its features, for if I do, I surely won't see it! I find it more rewarding to assume that most all objects can be seen in my telescope, and that way I do see more!

So keep the faith, "small telescope" owners. Put that dark cloth over your head to shield your dark-adapted eyes, use your averted vision, scan your eye around the field, scan the telescope, and you'll see those unseeable objects.

JOHN J. BROOKS
Goleta, Calif.

Mr. Brooks / You quote from the captions to Jack Newton's photos which were written by the editor who has never had a satisfactory view of these objects through a telescope under 12 inches aperture. Your perseverance, good eyesight and excellent location are the envy of many of us. But the next clear evening, we'll try again.

Sir / I am a rather advanced amateur astronomer, so I have been able to identify everything I have seen until Dec. 21, 1974 at 12:09 a.m. EST. While looking at Saturn through my six inch reflector at 133 power, I saw an object traverse the field traveling at approximately 1/2 degree per second of time. The object was red, about 9.5 magnitude, and moved from west to east. I tried to follow it, but couldn't find it again. My telescope was stationary — therefore, it wasn't a reflection. About an hour before the incident I saw the six day old orange-red moon near the horizon. This is why I hypothesize that the object might have been a high altitude aircraft or an artificial satellite (at about 500 miles altitude) reflecting the light of the setting moon. The incident happened at 52 minutes after moonset. Is it possible to see an aircraft or satellite by reflected moonlight in a six inch telescope?

DAN DINKEL
Jeffersonville, Ind.

Dear Mr. Dinkel / Yours was a most remarkable observation. A high flying aircraft reflecting moonlight seems unlikely since the moon was below the horizon for it, as well as you, at the time you mention. Your second suggestion of atmospherically reddened moonlight faintly illuminating a satellite is intriguing. If this is what you saw, it was the result of an exceedingly rare combination of circumstances — so rare in fact that we are inclined to think the odds favor a red light on a distant aircraft.

Sir / We are writing in reference to the recent letters you received about the satellite-like object seen the morning of July 17, 1974. We camped out on the night of July 16-17 to photograph the moon-Venus occultation early that morning. Taking advantage of the clear night, however, we decided to photograph some star fields and constellations — including some of the Milky Way region from Cygnus to Cassiopeia. One of us photographed from about 12:10 to 1:20 a.m. EDT while the others made some rich-field observations of the Milky Way in the Cygnus area at the same time. We did not notice any strange objects, nor were any recorded photographically on about eight exposures made at the time and in the area reported by Robert Purdy in his letter (December 1974 issue). It must be understood that we do not challenge the observing abilities of Purdy and the others who saw the unusual objects, nor do we deny their existence. Three of us, however, were observing in that general area of the sky from 12:00 to 2:00 a.m. EDT on July 17, and an erratically moving "first magnitude star" would not have escaped our notice — and certainly would not have escaped our photographic apparatus which was operating at precisely that time. Whatever the objects were, they were not visible in the southwestern Connecticut area. In fact, the night of July 16-17 was considered a routine night until we were all startled by the UFO letters.

RON GEROLA
RICK BRIA
ROB CHRISTIANSEN
Greenwich, Conn.

Gentlemen / UFO sightings made by experienced amateur astronomers are far more reliable than similar reports from nonastronomy enthusiasts, and thus are worth pursuing as far as possible. Your report and that of Robert Purdy are not necessarily in conflict. What they do indicate is that the observed object was probably not an artificial satellite at an altitude above 250 miles or so because it would have been visible from both locations. A lower object would appear high in the sky from the Philadelphia area but near the horizon and faint at your site.

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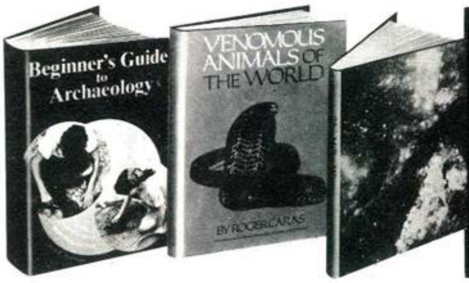
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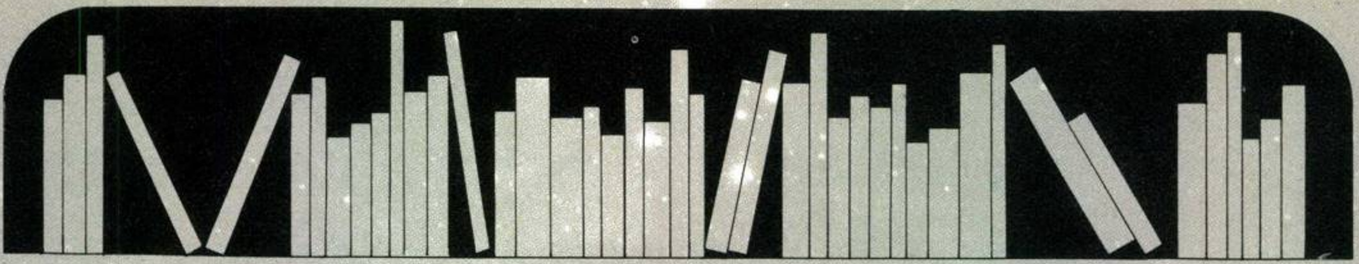

ASTRONOMY REVIEWS

Pioneer Odyssey — Encounter With a Giant

by RICHARD O. FIMMEL,
WILLIAM SWINDELL and
ERIC BURGESS

171 pages, paperback, $5.50*
U.S. Government Printing Office (1974)

Pioneer 10's epic, billion mile voyage to Jupiter represents our boldest reach into the outer solar system. Now NASA has summarized the historic mission in **Pioneer Odyssey — Encounter With a Giant.** Eight well-written chapters and dozens of top quality diagrams, color paintings and photographs trace the flight from conception to completion.

We are especially impressed by the volume's clarity and thoroughness. Chapters devoted to Pioneer 10's construction and its science packages carefully wade through technical material in an enjoyably understandable way. But don't get the idea that the book is preoccupied with the mission's nuts and bolts. The opening chapter deals strictly with explaining current concepts of Jupiter. Another chapter reviews Pioneer's findings in interplanetary space and the craft's nonphotographic data from Jupiter.

The last chapter is the book's most fascinating. In a parade of spectacular close-up color pictures, the authors step-by-step describe surprises that scientists found in Jupiter's markings — for example, the presence of a newborn, second Red Spot, and the existence of a monstrous white plume spewing out above the Jovian cloudtops.

Pioneer Odyssey — Encounter With a Giant is a must for any space enthusiast's library. More importantly, it's the most concise treatment of the expedition that will probably ever be published. Although Pioneer 11's follow-up Jupiter flyby in December 1974 uncovered additional surprises, don't hold out and wait for a book on its flight. Pioneer 11's mission will not be completed until it visits Saturn — around 1979.

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Mathematical Astronomy for Amateurs

by ERNEST A. BEET

143 pages, hardcover, $7.95
W.W. Norton and Company (1972)

An Introduction to Experimental Astronomy

by ROGER B. CULVER

195 pages, paperback, $4.00
W.H. Freeman and Company (1974)

If there is a music of the spheres, the orchestration is written in mathematics. Anyone seriously interested in understanding astronomy should master the basic mathematical principles of geometry, trigonometry, and algebra, and from there, eventually proceed into calculus, statistics, and differential equations.

Unfortunately, most mathematics textbooks seem to have never heard of astronomy, and most astronomy books give only a brief overview of the principles needed to understand mathematical astronomy. Now we have two new books which attempt to bridge this gap.

Both books have the same basic structure — introduction to mathematical principles, examples of these principles in astronomy, and experiments (or experimental data already gathered) to illustrate the principles. Mathematical astronomy is such a wide field that both books cover different areas without much overlap. The approach used is an excellent one, and the resulting program of instruction in mathematics is enjoyable, understandable and useful.

Beet's book was originally published in Great Britain, which explains certain cryptic phrases occasionally found in the text. It starts with basics about Earth, the moon, and their orbits. Time and the celestial sphere are described in detail. Kepler's laws are explained (their derivation is left to a more advanced book), and certain aspects of stellar astronomy appear in examples about absolute versus apparent magnitude, parallax, and the mass of binary stars. (Now you can see where all the numbers in the textbooks really come from.)

Altogether it is a valuable book — probably the first of the two you should read. A series of "make it yourself" astronomical tools will be of interest to amateur astronomers. It is possible to quibble with the author on a very few explanations, but they do not detract from the lessons to be learned.

Culver's book was designed as a workbook for a college level introduction to astronomy. Despite the title, the student makes no experiments. All the experimental data is displayed on reproduced charts and photographs, and the student must analyze the material and extract results (in accordance with instructions and equations) from the raw data.

Through the use of the 22 experiments, a student with knowledge of high school mathematics can determine the speed of light, find the trans-Uranian planet, measure planetary atmospheres and masses, and carry out a series of fascinating exercises with stellar and galactic sources. For example, the data leading to the determination of the Hubble constant is presented for analysis.

Excellent appendixes and tables are found in the back of the book, but in doing so the author seems to be trying to make this single book self-sufficient. That is a poor practice for teaching astronomy, since looking things up in other books (and finding the other books in the first place) is part of the learning process. Furthermore, there is no answer section to the book so a teacher must make up his own instructor's guide, and a casual reader will be unable to check his own answers.

If the books suffer from a serious weakness, it is in their cursory treatment of the role of electronic computers in mathematical computation for astronomy. Computers today calculate, measure, catalog and compare data, but according to these books it is all done by hand. As a beginning, however, the books are more than sufficient.

◆

New From Astronomy

The 1975 Trifid Calendar

1975 has arrived. And in keeping with ASTRONOMY's Orion Calendar of last year, we've designed an even more unique calendar wall poster.

This beautiful 22 x 34 inch poster shows a blowup view of the Trifid nebula – one of the most colorful jewels of the universe – in the constellation Sagittarius. The photograph – one of the sparkling, new color photographs from Kitt Peak National Observatory – has never been published this large before. Gossamer shadings of red and blue draw your mind into the depths of the awesome universe.

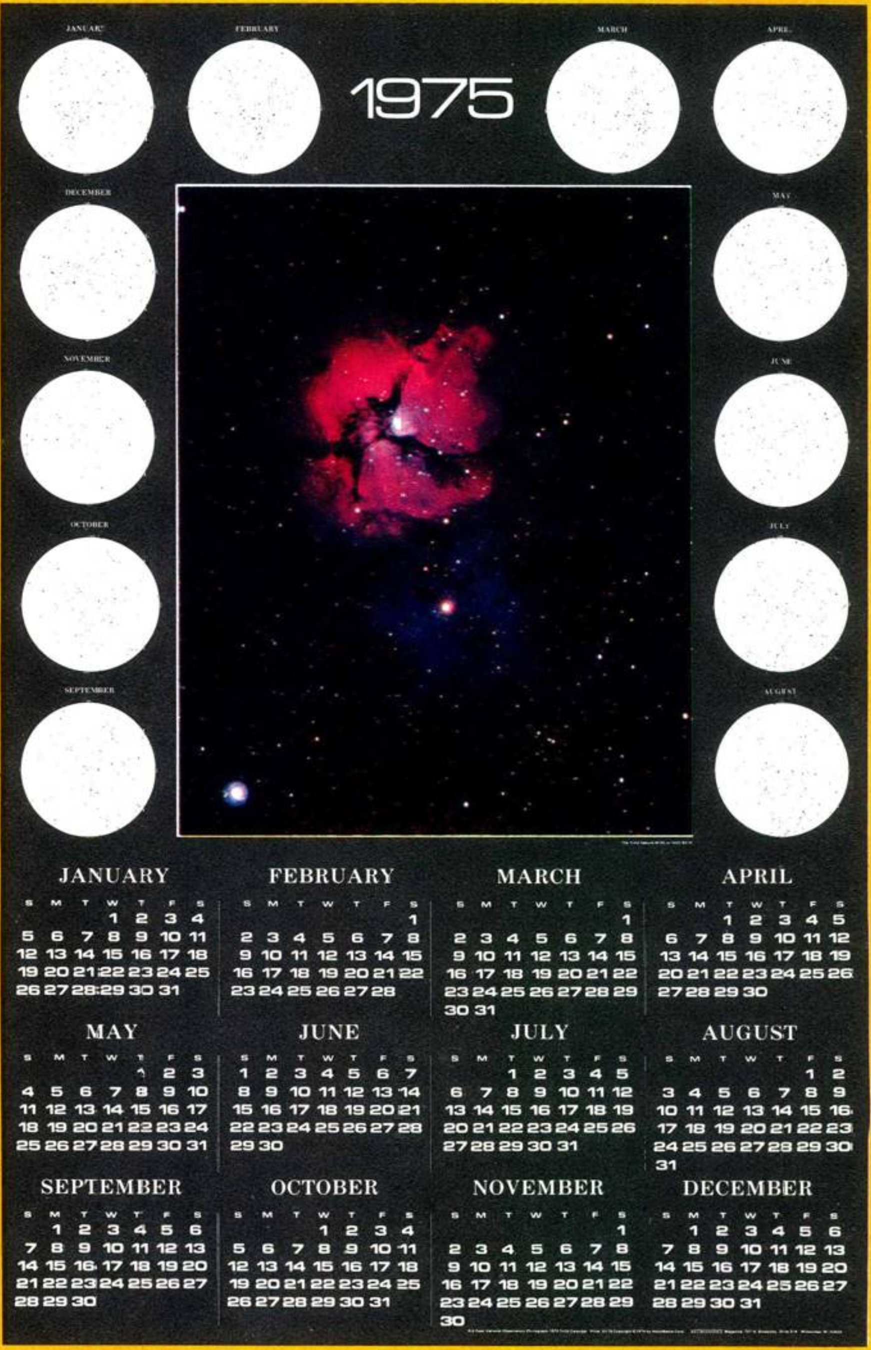
Surrounding the photograph are 12 sky maps, one for each month of the year – making the 1975 Trifid Calendar not only beautiful but doubly useful. At the end of the year, all you have to do is cut off the calendar portion – and you will have a wall hanging of lasting beauty and value.

This lithographed reproduction is printed on heavy gloss paper and has a protective varnish coating. And to insure that the Trifid Calendar reaches you in A-1 condition, it will be rolled – not folded – and shipped to you in a mailing tube via first class mail.

Price: $3.75 each (includes first class postage)

Sorry – calendars may not be billed.

ASTRONOMY Magazine,
757 N. Broadway,
Suite 204,
Milwaukee, WI 53202



JANUARY

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31						

SEPTEMBER

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14	15	16	17	18	19	20
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OCTOBER

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NOVEMBER

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DECEMBER

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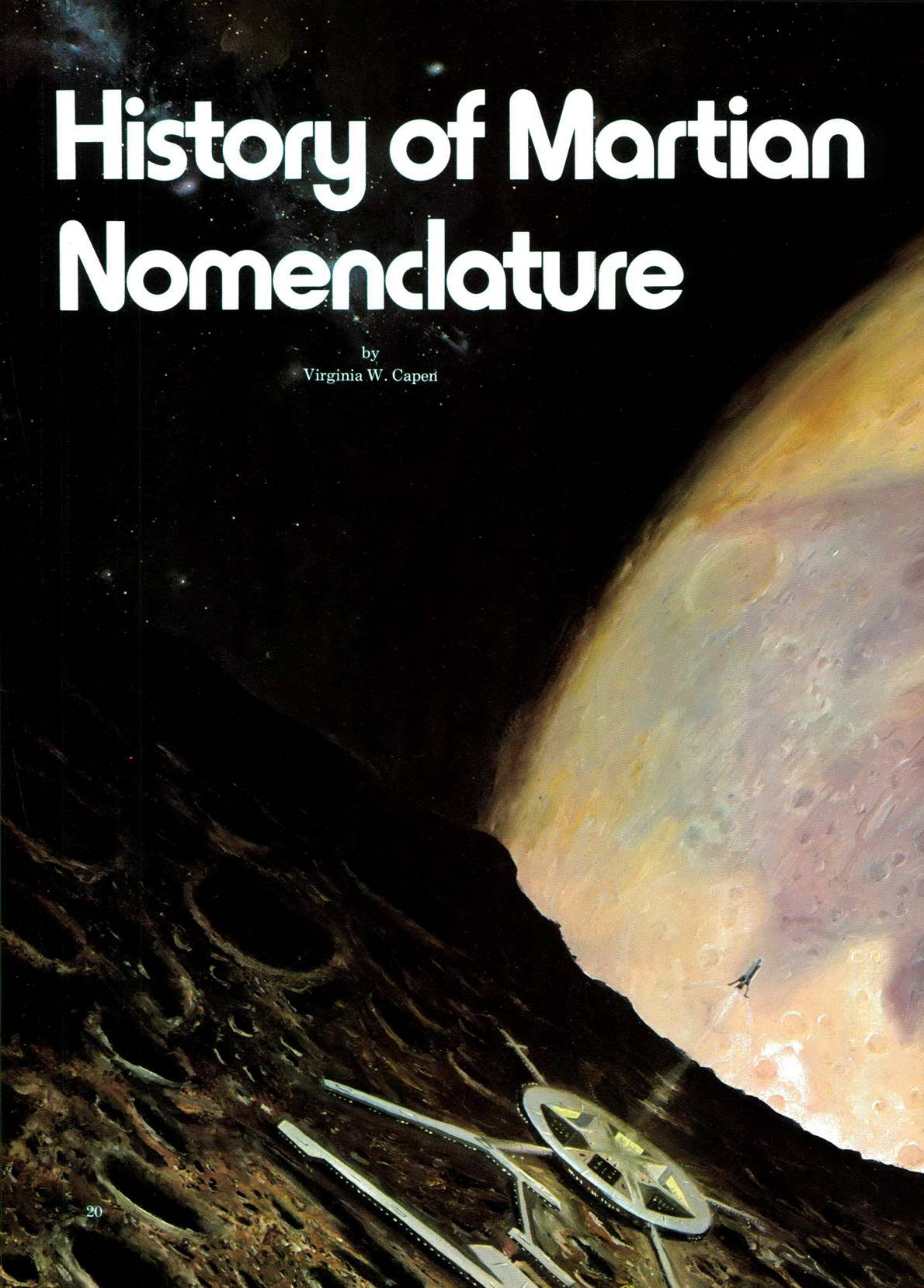
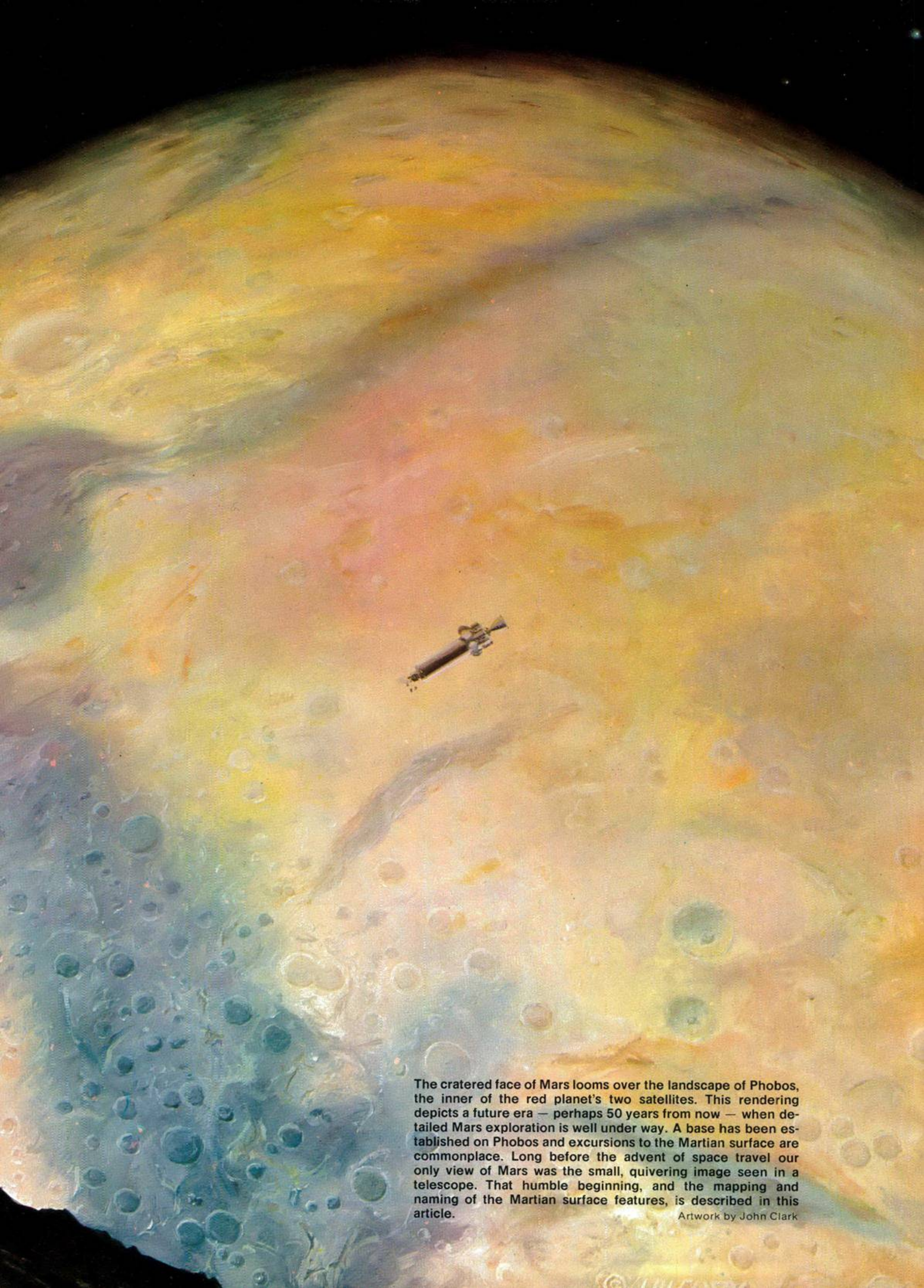
Actual Size: 22" x 34"

History of Martian Nomenclature

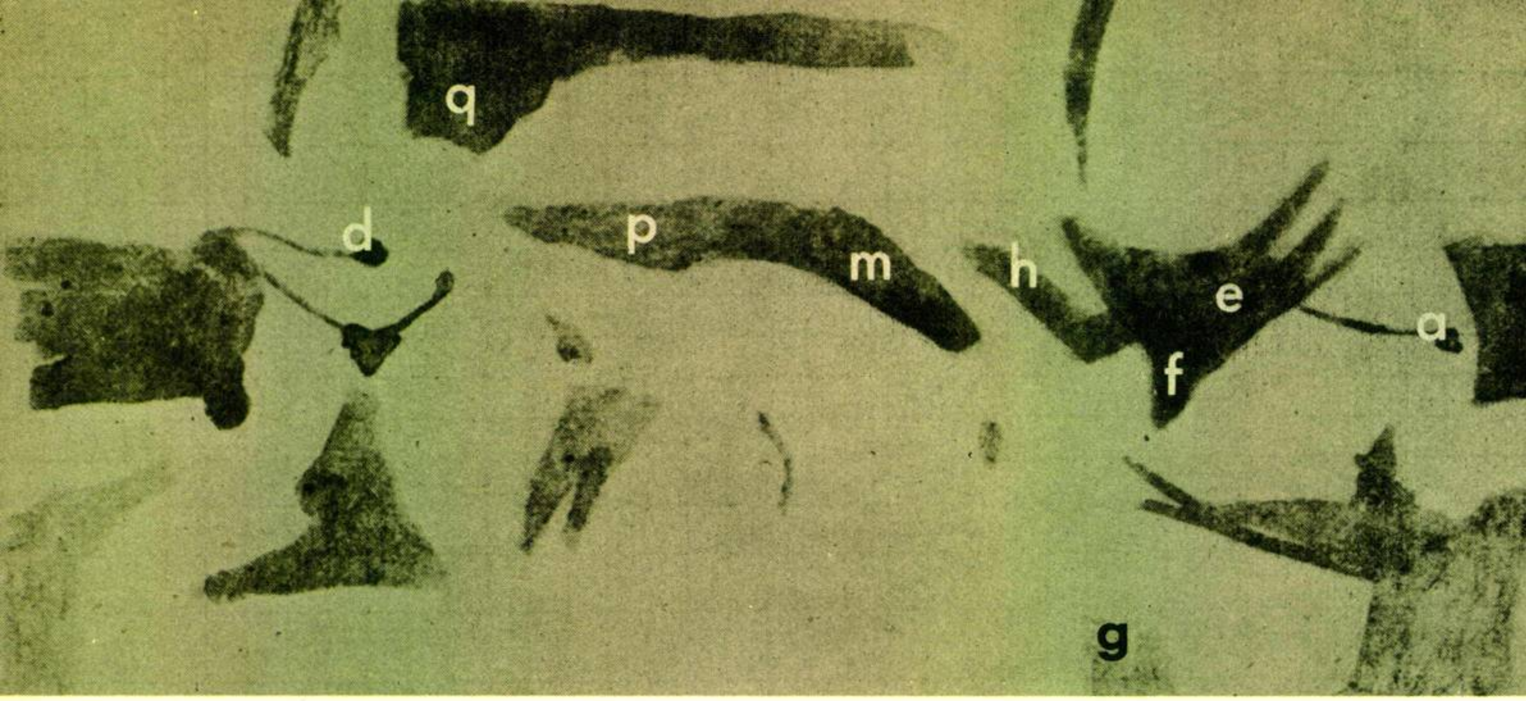
by
Virginia W. Capen





The cratered face of Mars looms over the landscape of Phobos, the inner of the red planet's two satellites. This rendering depicts a future era — perhaps 50 years from now — when detailed Mars exploration is well under way. A base has been established on Phobos and excursions to the Martian surface are commonplace. Long before the advent of space travel our only view of Mars was the small, quivering image seen in a telescope. That humble beginning, and the mapping and naming of the Martian surface features, is described in this article.

Artwork by John Clark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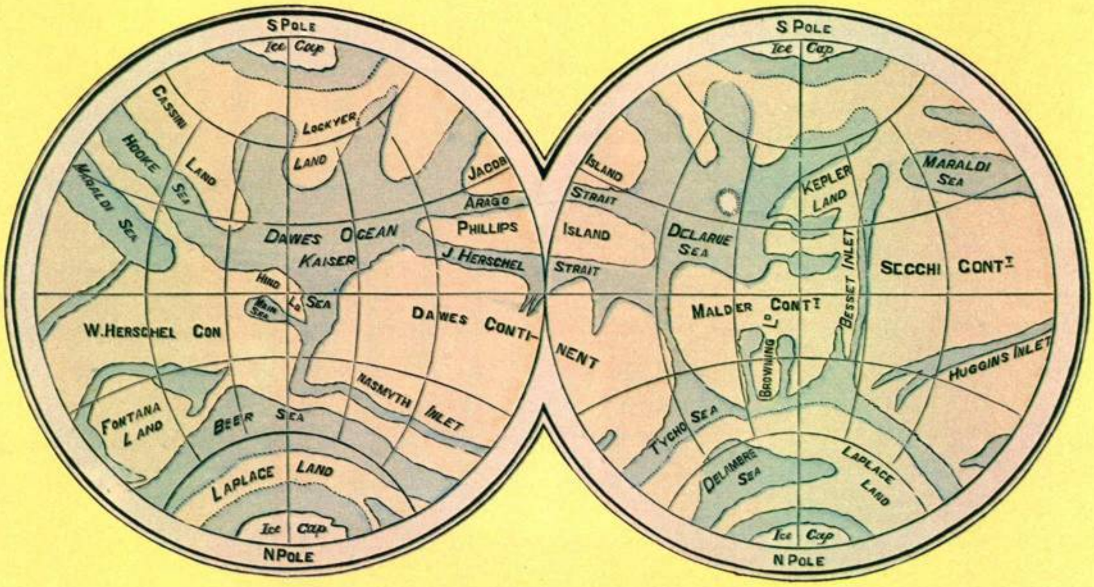
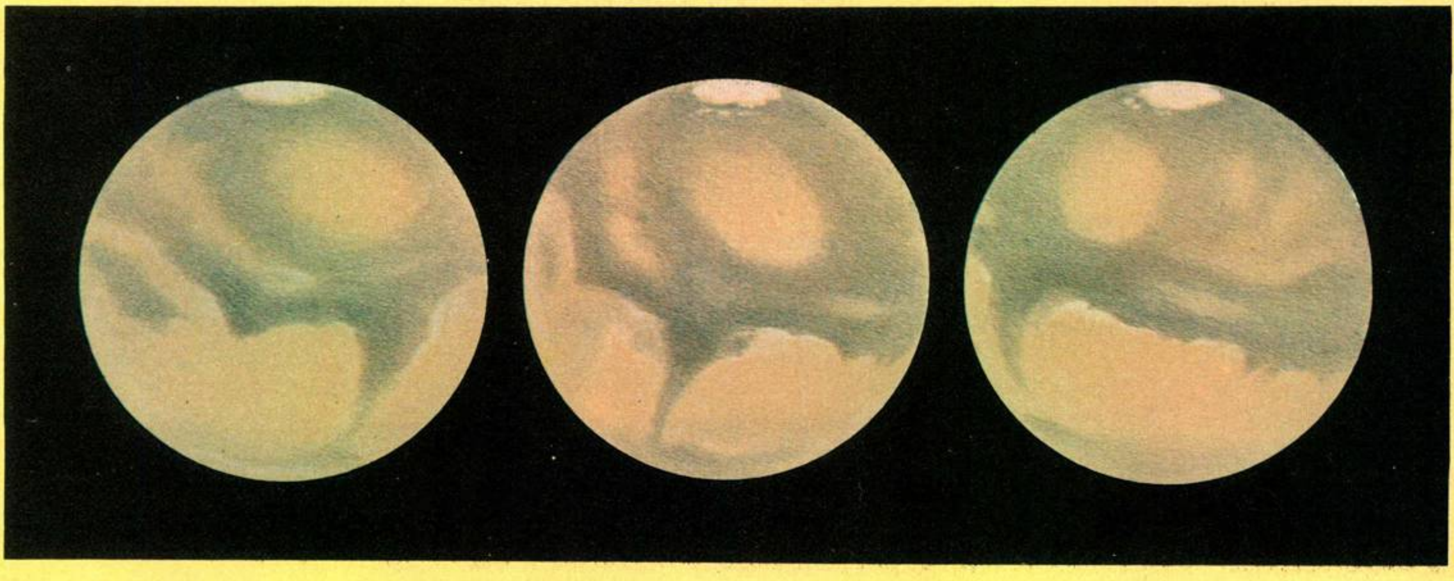

S POLE
Ice Cap
CASSINI
LOCKYER
HOOKE
LAND
SEA
LAND
MARALDI SEA
JACOB
ARAGO
PHILLIPS
DAWES OCEAN
KAISER
J HERSCHEL
HIND
LO SEA
W. HERSCHEL CON
DAWES CONTI-
NENT
NASMYTH INLET
FONTANA LAND
BEER SEA
LAPLACE LAND
Ice Cap
N POLE
S POLE
Ice Cap
ISLAND
STRAIT
ISLAND
STRAIT
MARALDI SEA
KEPLER LAND
DCLARUE SEA
BESSET INLET
SECCHI CONT^T
MALDER CONT^T
BROWNING L^D
HUGGINS INLET
TYCHO SEA
DELAMBRE SEA
LAPLACE LAND
Ice Cap
N POLE



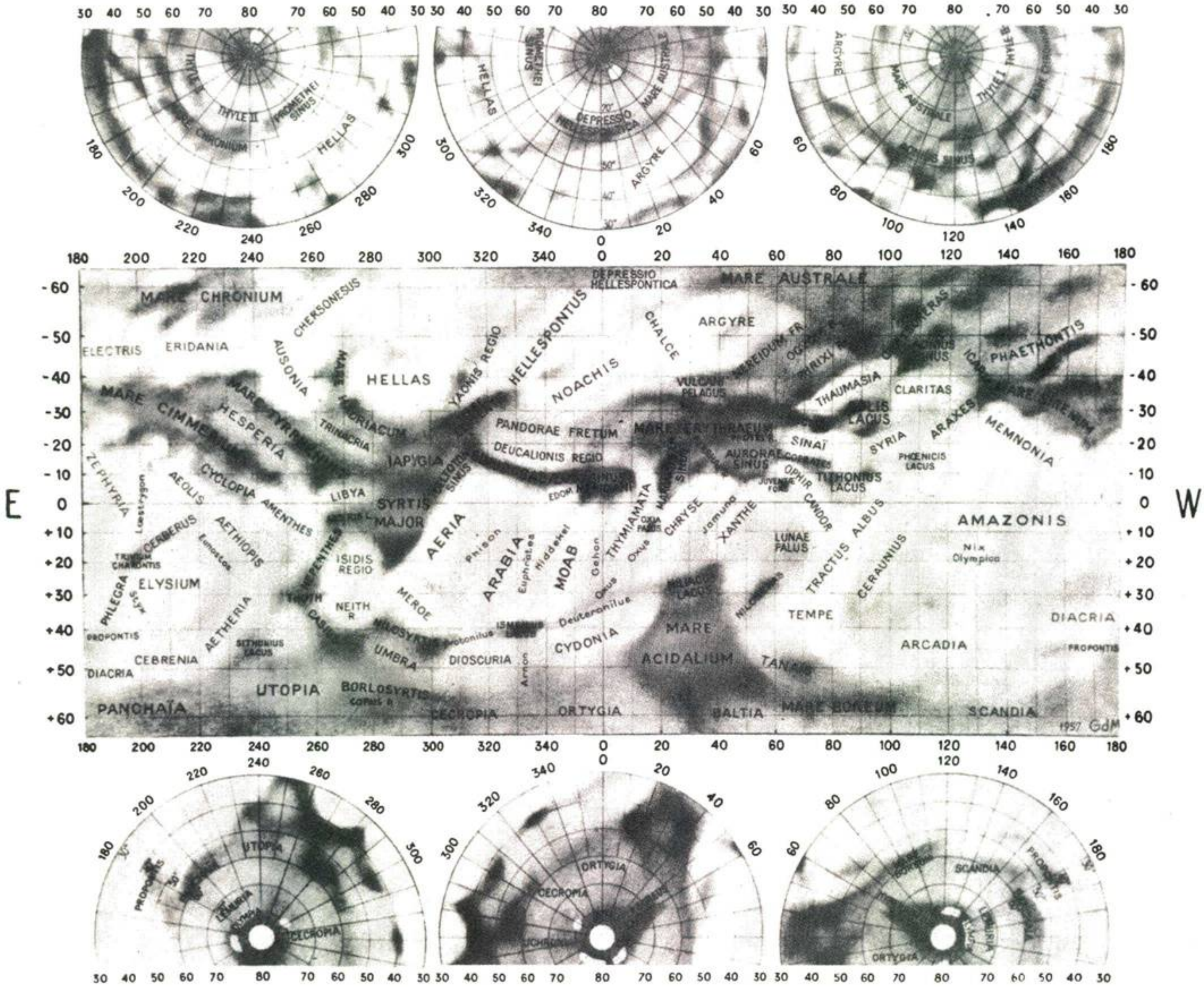
Sometime in the next century, explorers from Earth may be living and working on the slopes of Pavonis Mons, a gigantic volcanic mountain on the planet Mars. Other bases might be established on the floor of the four mile deep Martian rift canyon Vallis Marineris. Yet both of these massive features were discovered only three years ago, and named even more recently.

Distant worlds and the features on them have always intrigued man. "What's it like on Mars?" is a question we can now answer with considerable accuracy. Soon we will have precise details.

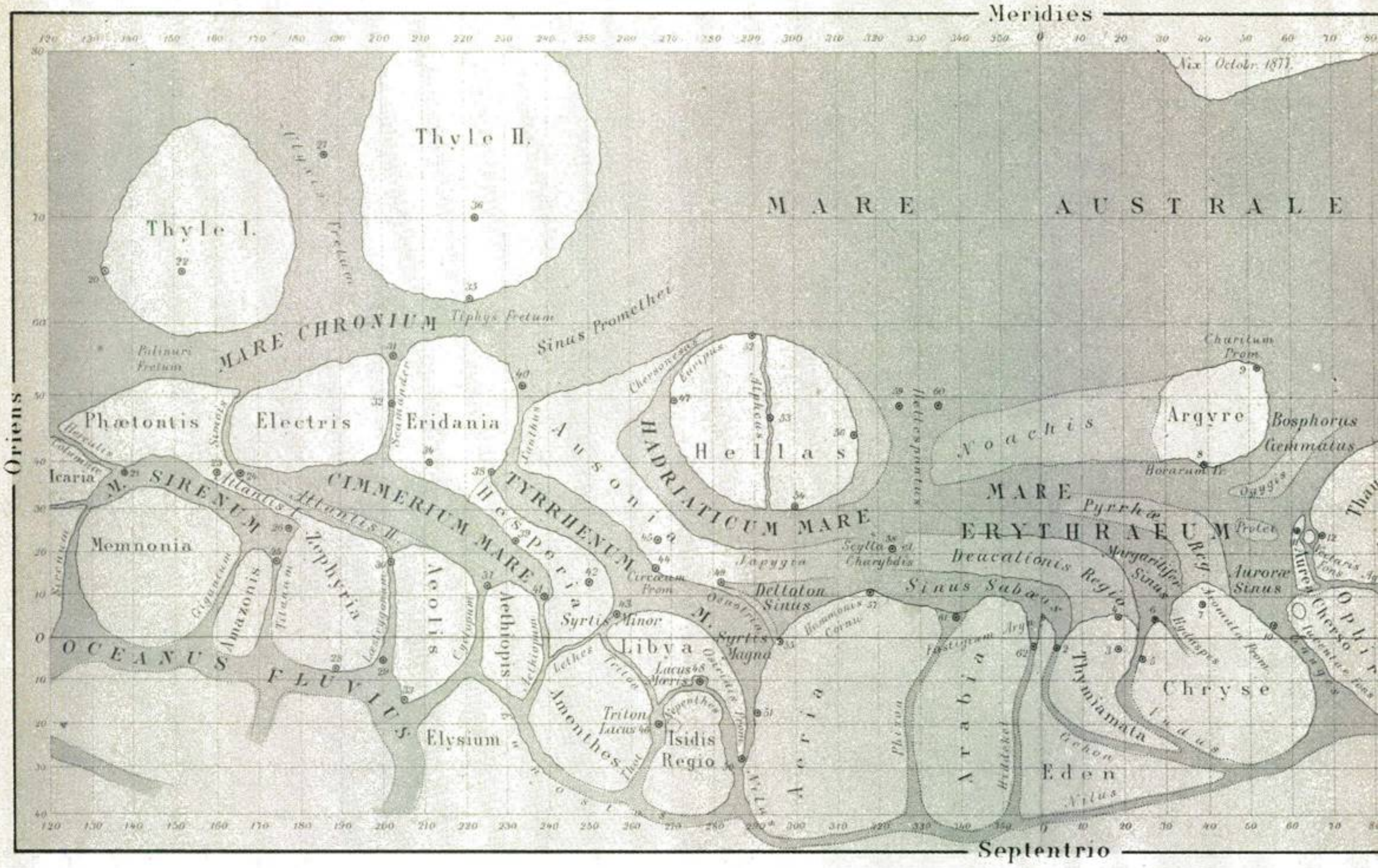
Looking back into the history of Mars exploration, there was a period not too many years ago when hardly anything was known about Mars and nothing whatever was known of its spectacular volcanos and valleys.

Perhaps no historical documents measure more graphically man's progressive understanding of the world of Mars than do his cartographic arts. Each epoch of advancement has been reflected in Martian charts painstakingly prepared during the last 140 years of telescopic observation. Unlike most map-

One of the earliest charts of Mars (top) was constructed about 1834 from drawings made in 1830 and 1832 by Wilhelm Beer and J.H. von Madler. They used single letters of the alphabet to identify the chief light and dark markings on their early maps of Mars; the major features differ little from those on our modern charts. At center is the chart drawn in 1867 by the English astronomer, Richard Anthony Proctor, who named the Martian features after observers of the red planet. This is the first Martian map in which a system of names was used to identify the features. Some of the Mars drawings made by N.E. Green in 1877 are shown below. They are among dozens that Green used to construct the map on page 28. (South is shown up in all Mars maps prior to spacecraft exploration.)

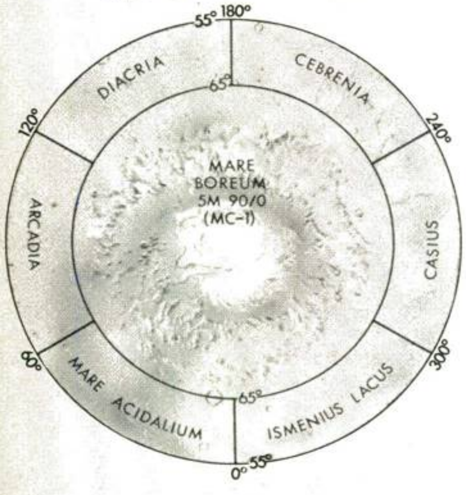

E
W
MARE CHRONIUM
CHERSONESUS
ELECTRIS
ERIDANIA
AUSONIA
HELLAS
YAONIS REGIO
HELLESPONTUS
NOACHIS
CHALCE
DEPRESSIO HELLESPONTICA
MARE AUSTRALE
ARGYRE
PHAETHONTIS
MARE CIMMERIUM
HESPERIA
MARE TYRRHENUM
TRINACRIA
PANDORAE FRETUM
DEUCALIONIS REGIO
VULCANI PELAGUS
THAUMASIA
CLARITAS
SOLIS LACUS
MEMNONIA
ARAXES
SYRIA
SINAI
AURORAE SINUS
PHOENICIS LACUS
ZEPHYRIA
AEOLIS
CYCLOPIA
AMENTHES
LIBYA
IAPYGIA
SYRTIS MAJOR
EDOM
TITHONIUS LACUS
OPHIR
CANDOR
CHRYSE
XANTHE
AMAZONIS
CERBERUS
AETHIOPIS
ISIDIS REGIO
AERIA
ARABIA
MOAB
THYMIAMATA
LUNAE PALUS
TRACTUS ALBUS
CERAUNIUS
Nix Olympica
ELYSIUM
PHLEGRA
AETHERIA
NEITH R
MEROE
CYDONIA
MARE ACIDALIUM
NILIACUS LACUS
TEMPE
DIACRIA
ARCADIA
PROPONTIS
CEBRENIA
UMBRA
DIOSCURIA
TANAIS
UTOPIA
BORLOSYRTIS
PANCHAIA
CECROPIA
ORTYGIA
BALTIA
MARE BOREUM
SCANDIA
1957 GdM

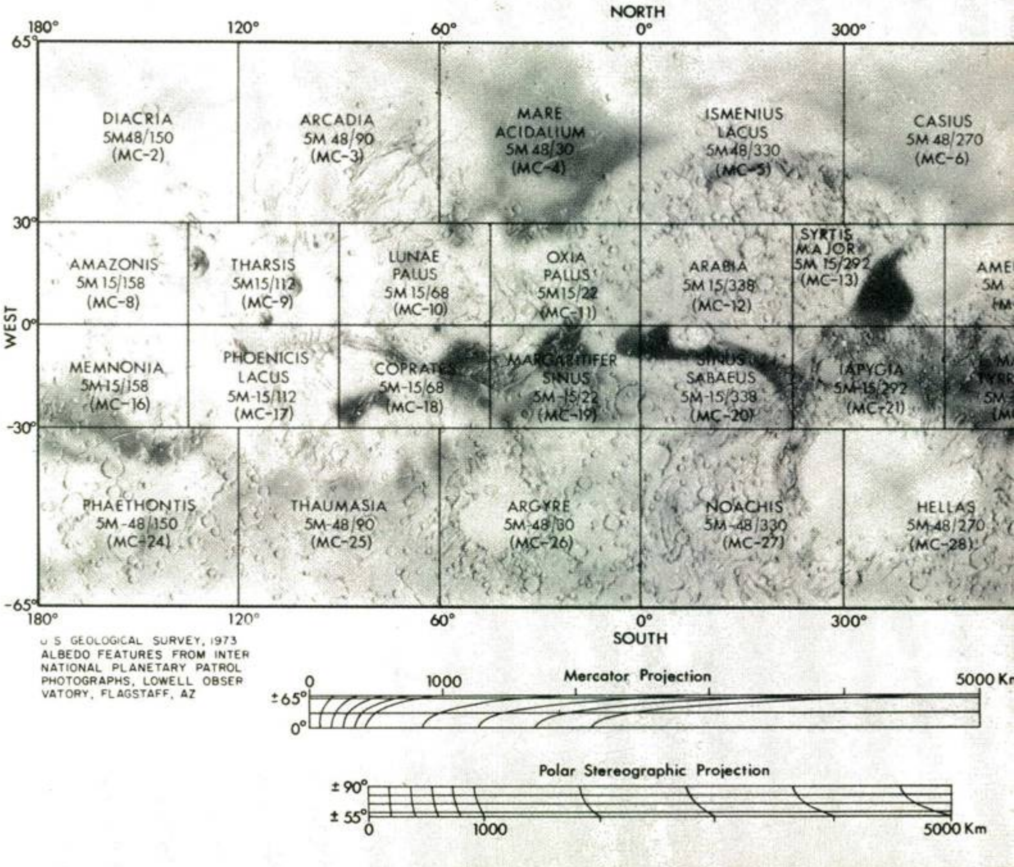
Before the Mariner spacecraft revolutionized Martian cartography this was the "official" Mars map. It is a Mercator map with polar projections showing the principal albedo features for the years 1941 to 1952 and the 128 official IAU feature names as adopted in 1958. Certain permanent and traditional feature names were dropped or changed, or their locations changed from those marked by their originators. Names misspelled on original map have been corrected by author.


Meridies
Septentrio
Oriens
Nix Octobr. 1877
Thyle I.
Thyle II.
MARE AUSTRALE
MARE CHRONIUM
Tiphys Fretum
Sinus Promethei
Palinuri Fretum
Phætontis
Electris
Eridania
Ausonia
Chersonesus
Hellas
HADRIATICUM MARE
Hellespontus
Noachis
Argyre
Charitum Prom.
Bosphorus Gemmatus
Icaria
M. SIRENUM
CIMMERIUM MARE
TYRRHENUM MARE
Hesperia
Memnonia
Zephyria
Amazonis
Aeolis
Aethiopis
Syrtis Minor
Libya
M. Syrtis Magna
Deltoton Sinus
Iapygia
Scylla et Charybdis
Deucalionis Regio
MARE ERYTHRAEUM
Pyrrhae Regio
Margaritifer Sinus
Sinus Sabaeus
Aurorae Sinus
Aurea Cherso
Ophir
Chryse
Arabia
Aeria
Eden
Thymiamata
Gehon
Nilus
Hiddekel
Indus
Hydaspes
OCEANUS FLUVIUS
Elysium
Amenthes
Lacus Moeris
Triton Lacus
Isidis Regio
Nepenthes
Atlantis I.
Atlantis II.
Titanum
Gigantum
Cyclopum
Lethes
Thoth
Nilosyrtis
Fastigium Aryn
Hammonis Cornu
Circaeum Prom.

NORTH POLAR REGION

POLAR CAP AS IT APPEARED ON OCTOBER 12, 1972


180°
55°
65°
DIACRIA
CEBRENIA
120°
240°
MARE BOREUM 5M 90/0 (MC-1)
ARCADIA
CASIUS
60°
300°
MARE ACIDALIUM
ISMENIUS LACUS
0°


NORTH
SOUTH
WEST
180°
120°
60°
0°
300°
65°
30°
0°
-30°
-65°
DIACRIA 5M48/150 (MC-2)
ARCADIA 5M 48/90 (MC-3)
MARE ACIDALIUM 5M 48/30 (MC-4)
ISMENIUS LACUS 5M48/330 (MC-5)
CASIUS 5M 48/270 (MC-6)
AMAZONIS 5M 15/158 (MC-8)
THARSIS 5M15/112 (MC-9)
LUNAE PALUS 5M 15/68 (MC-10)
OXIA PALUS 5M15/22 (MC-11)
ARABIA 5M 15/338 (MC-12)
SYRTIS MAJOR 5M 15/292 (MC-13)
MEMNONIA 5M-15/158 (MC-16)
PHOENICIS LACUS 5M-15/112 (MC-17)
COPRATES 5M-15/68 (MC-18)
MARGARITIFER SINUS 5M-15/22 (MC-19)
SINUS SABAEUS 5M-15/338 (MC-20)
IAPYGIA 5M-15/292 (MC-21)
PHAETHONTIS 5M-48/150 (MC-24)
THAUMASIA 5M-48/90 (MC-25)
ARGYRE 5M-48/30 (MC-26)
NOACHIS 5M-48/330 (MC-27)
HELLAS 5M-48/270 (MC-28)
Mercator Projection
±65°
0°
0
1000
5000 Km
Polar Stereographic Projection
±90°
±55°
0
1000
5000 Km

U S GEOLOGICAL SURVEY, 1973
ALBEDO FEATURES FROM INTERNATIONAL PLANETARY PATROL PHOTOGRAPHS, LOWELL OBSERVATORY, FLAGSTAFF, AZ

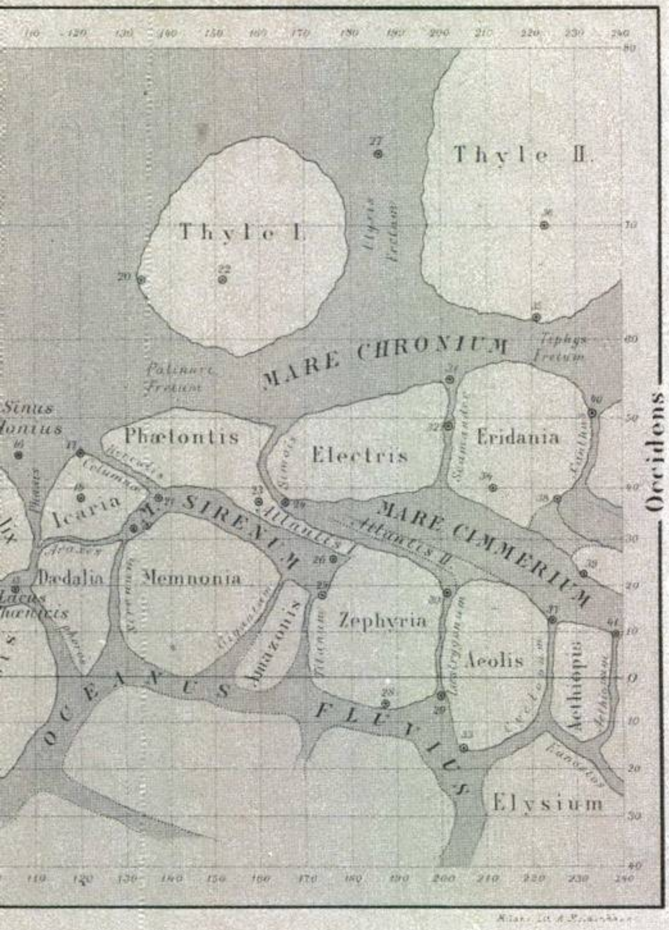
making efforts, the early charts of Mars did not serve as navigational aids to man. Instead they found themselves in relative seclusion to be used as scientific instruments of the astronomer-explorer for plotting the mysterious deviations on the Martian surface and for studying the seasonal meteorological changes of the atmosphere of the red planet.

MARTIAN FEATURES

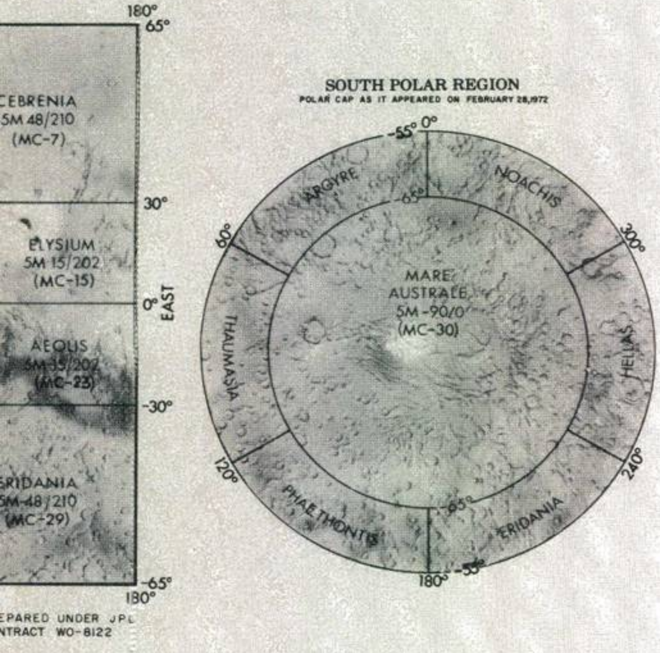
Name		Feature
Catena	(kay-TAN-na)	crater chain
Chasma	(KAZ-ma)	canyon
Dorsum	(DOOR-sum)	ridge
Fossae	(FOSS-say)	long, shallow ditches
Labyrinthus	(law-BRIN-tooz)	valley complex
Mensae	(MEN-say)	mesas
Mons	(MOANZ)	mountain
Montes	(MOAN-tez)	chain of mountains
Patera	(pat-TERRA)	complex or irregular crater
Planitia	(plan-NEE-she-a)	plain
Planum	(PLAN-num)	plateau
Tholus	(TOE-loose)	hill
Vallis	(VAL-lis)	sinuous valley
Vastitas	(vah-SEE-tass)	extensive plain

Although Mars has a diameter of only a little over half that of Earth, the first charts showed the nearby planet to be not as small as first impressions implied. The total Martian surface area — as observed and mapped by the astronomer-cartographer — was found to be slightly greater than that of Earth, due to the lack of large surface waters on Mars. The genesis of Martian nomenclature used to describe this vast area developed from different linguistic origins and philosophies of the mapmakers. Consequently several systems of nomenclature evolved in parallel over the last century.

During the 19th and early 20th centuries the observation, cartography, and identifying nomen-

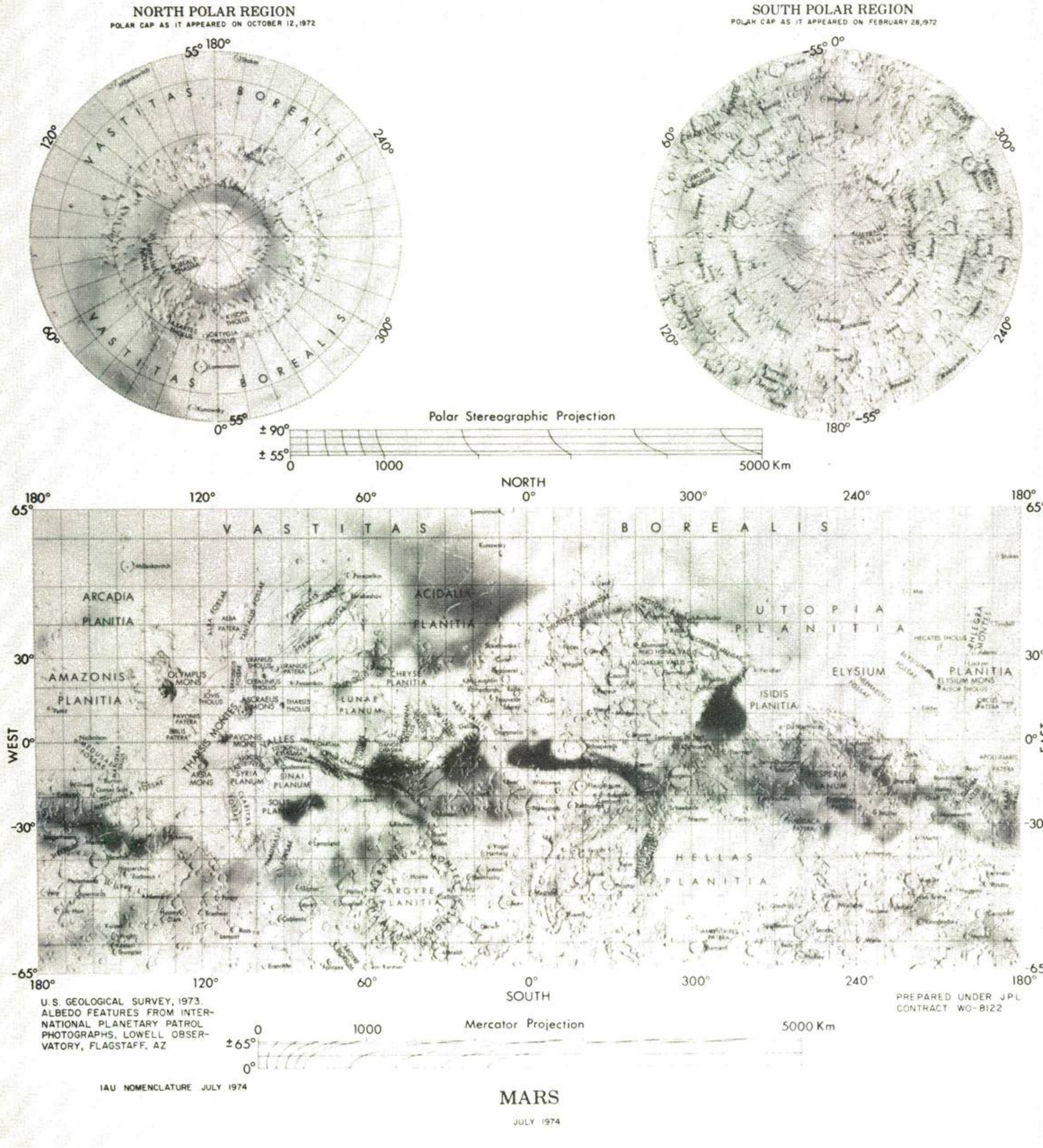

Thyle I.
Thyle II.
MARE CHRONIUM
Phaetontis
Electris
Eridania
Sinus Ionius
Icaria
MARE SIRENUM
MARE CIMMERIUM
Memnonia
Daedalia
Zephyria
Aeolis
Amazonis
Aethiops
OCEANUS
FLUVIUS
Elysium
Occidens

During the close approach of Earth and Mars in 1877, Giovanni V. Schiaparelli made this map of the red planet. To accurately locate the features, he timed passage of 62 surface points as they were carried past the central meridian by Mars' rotation. The discovery of many new markings on Mars compelled Schiaparelli to invent a new systematic nomenclature scheme that used Latinized forms of names from the geography of ancient lands and mythologies. These names added to the lore and romance of the red planet for many decades.


180°
65°
CEBRENIA
5M 48/210
(MC-7)
30°
ELYSIUM
5M 15/202
(MC-15)
0°
EAST
AEOLIS
5M-15/202
(MC-23)
-30°
ERIDANIA
5M-48/210
(MC-29)
-65°
180°
EPARED UNDER JPL
NTRACT WO-8122
SOUTH POLAR REGION
POLAR CAP AS IT APPEARED ON FEBRUARY 28,1972
-55° 0°
ARGYRE
NOACHIS
-65°
60°
300°
MARE AUSTRALE
5M-90/0
(MC-30)
THAUMASIA
HELLAS
120°
240°
PHAETHONTIS
ERIDANIA
180°
-55°

The globe of Mars has been divided into 30 zones named after their most prominent features. Detailed maps of each zone are currently in preparation. The area labeled Syrtis Major and surrounding territory is shown in the artist's rendering at the beginning of this article.

clature of the planet Mars was the interest of a small group of astronomers. The first chart was constructed around 1834 by lunar cartographers Wilhelm Beer and Johann Heinrich von Madler from visual drawings they made in 1830 and 1832 with a Fraunhofer four inch achromatic refracting telescope. Their private observatory was located in the Berlin Tiergarten. They used single letters of the alphabet to identify the basic light and dark markings on their two-hemisphere orthographic type chart. Later observations made from 1835 to 1839 with a nine inch telescope were used to complete north and south polar projection maps published in 1840.


NORTH POLAR REGION
POLAR CAP AS IT APPEARED ON OCTOBER 12, 1972
VASTITAS BOREALIS
SOUTH POLAR REGION
POLAR CAP AS IT APPEARED ON FEBRUARY 28, 1972
Polar Stereographic Projection
± 90°
± 55°
0
1000
5000 Km
NORTH
180°
120°
60°
0°
300°
240°
65°
30°
0°
-30°
-65°
WEST
VASTITAS BOREALIS
ARCADIA PLANITIA
ACIDALIA PLANITIA
UTOPIA PLANITIA
AMAZONIS PLANITIA
OLYMPUS MONS
CHRYSE PLANITIA
LUNAE PLANUM
ELYSIUM PLANITIA
ISIDIS PLANITIA
THARSIS MONTES
ARSIA MONS
SYRIA PLANUM
SINAI PLANUM
HESPERIA PLANUM
ARGYRE PLANITIA
HELLAS PLANITIA
SOUTH
U.S. GEOLOGICAL SURVEY, 1973.
ALBEDO FEATURES FROM INTERNATIONAL PLANETARY PATROL PHOTOGRAPHS, LOWELL OBSERVATORY, FLAGSTAFF, AZ
PREPARED UNDER JPL CONTRACT WO-8122
Mercator Projection
±65°
IAU NOMENCLATURE JULY 1974
MARS
JULY 1974

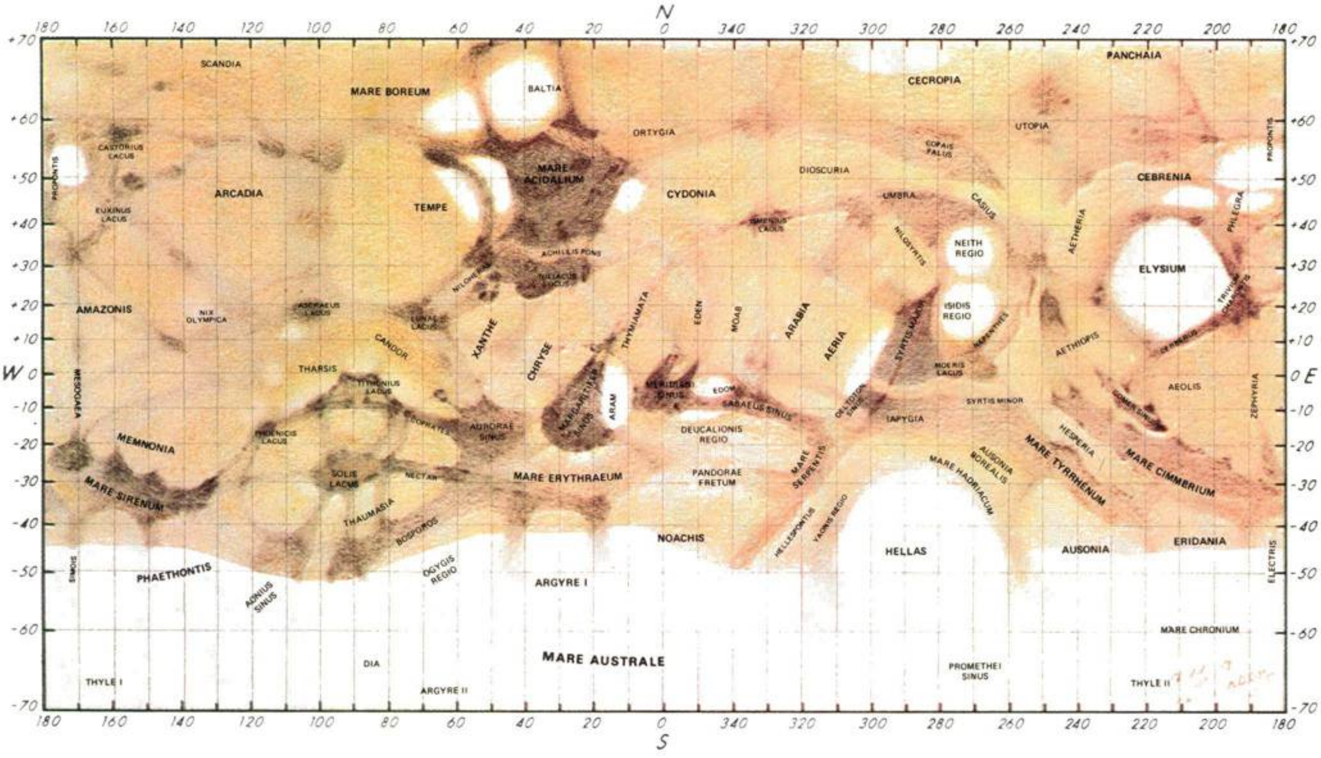

N
S
W 0
0 E
SCANDIA
MARE BOREUM
BALTIA
PANCHAIA
CECROPIA
UTOPIA
ORTYGIA
CASTORIUS LACUS
PROPONTIS
MARE ACIDALIUM
COPAIS PALUS
DIOSCURIA
CEBRENIA
ARCADIA
TEMPE
CYDONIA
UMBRA
CASIUS
EUXINUS LACUS
ISMENIUS LACUS
NILOSYRTIS
NEITH REGIO
AETHERIA
PHLEGRA
ACHILLIS PONS
NILIACUS LACUS
NILOKERAS
ELYSIUM
AMAZONIS
NIX OLYMPICA
ASCRAEUS LACUS
LUNAE LACUS
XANTHE
CHRYSE
THYMIAMATA
EDEN
MOAB
ARABIA
AERIA
SYRTIS MAJOR
ISIDIS REGIO
NEPENTHES
TRIVIUM CHARONTIS
CERBERUS
AETHIOPIS
CANDOR
THARSIS
TITHONIUS LACUS
MOERIS LACUS
AEOLIS
MESOGAEA
ARAM
MERIDIANI SINUS
EDOM
SABAEUS SINUS
DELTOTON SINUS
SYRTIS MINOR
IAPYGIA
GOMER SINUS
ZEPHYRIA
MEMNONIA
PHOENICIS LACUS
COPRATES
AURORAE SINUS
MARGARITIFER SINUS
DEUCALIONIS REGIO
HESPERIA
MARE TYRRHENUM
MARE CIMMERIUM
MARE SIRENUM
SOLIS LACUS
NECTAR
MARE ERYTHRAEUM
PANDORAE FRETUM
MARE SERPENTIS
MARE HADRIACUM
AUSONIA BOREALIS
THAUMASIA
BOSPOROS
NOACHIS
HELLESPONTUS
YAONIS REGIO
HELLAS
AUSONIA
ERIDANIA
SIMOIS
PHAETHONTIS
AONIUS SINUS
OGYGIS REGIO
ARGYRE I
ELECTRIS
MARE CHRONIUM
DIA
MARE AUSTRALE
PROMETHEI SINUS
THYLE I
ARGYRE II
THYLE II

Chart by C. F. Capen

This color schematic map of the Martian surface in northern summer and southern winter — using modern traditional terminology — is one of a set of color seasonal maps compiled from 1950-1966 observational data by C.F. Capen for the Mars Scientific Model, 1968, Jet Propulsion Laboratory, California Institute of Technology. This map represents the state of the art of visual Mars mapping prior to spacecraft exploration of the planet.

In 1858, the astute observer Father Pietro Angelo Secchi was the first person to assign names to several of the colored features that he observed repeatedly with his superior nine inch Merz telescope at the College Observatory of Rome. An improved Mars chart, made in 1864 by F. Kaiser at Leiden, Holland, did not identify the surface markings.

The first chart to use a system of names was drawn in 1867 by the English astronomer and author, Richard Anthony Proctor. Proctor used 27 drawings of Mars which were made by William R. Dawes in 1864-65 to produce a two-hemisphere orthographic chart. The Martian features were named after astronomers who had previously studied the planet — following the precedent set by G. B. Riccioli in naming the features of the moon. This nomenclature system was considered chauvinistic by European astronomers because Proctor had honored the English observers with the most prominent Martian features. The discovery of many new markings on Mars with a nine inch Merz refractor during the 1870s compelled the Italian astronomer Giovanni V. Schiaparelli, director of the Royal Observatory of Brera, to invent a new and romantic nomenclature scheme. The Schiaparelli system, employing names from the geography of ancient lands and mythologies in a Latinized form, neatly avoided any favoritism.

The Schiaparelli system was eventually accepted and is still used today. However, those tongue-twisting names make learning the face of Mars a tedious task. Their virtue is their unique association to Mars.

Although the accuracy and detail in Martian cartography improved after Schiaparelli's time, there were only minor changes made to his nomenclature system. Then came Mariner 9.

The successful 1971 orbiting of Mars by Mariner 9 and the subsequent acquisition of 7,232 high resolution photographs of topographic features raised the state of our cartographic knowledge of Mars immensely. The change was equal to a comparison of a map of the full moon made with binoculars and a lunar map of the early 1960s.

A new chart of Mars from the United states Geological Survey's *Atlas of Mars* (produced by the Department of Astrogeology at Flagstaff, Ariz.) shows telescopic albedo features, Mariner 9 topographical relief features and the new IAU approved nomenclature. North is shown up. Small scale, detailed charts of Mars based on Mariner 9 photography are in preparation.

A whole new scheme of topographic names was devised to extend and to be compatible with the existing Schiaparellian system by the Working Group on Martian Nomenclature of the International Astronomical Union. The entire surface of Mars was divided into 30 geometric regions — each designated by the name of a prominent classical telescopic feature within its confines.

Fourteen classes of Martian topographic features have now been recognized and given names. These topographic names are used as generic terms for the classical feature names originated by Schiaparelli and Antoniadi. For example, all plains on the planet are now called Planitia — so the plain in

This old but excellent chart of Mars drawn by N.E. Green is based on observations made by experienced planetary observers from 1873 to 1877. The nomenclature, with few exceptions, is that employed by Proctor in his 1867 chart of Mars. A few new feature names were added by Green.

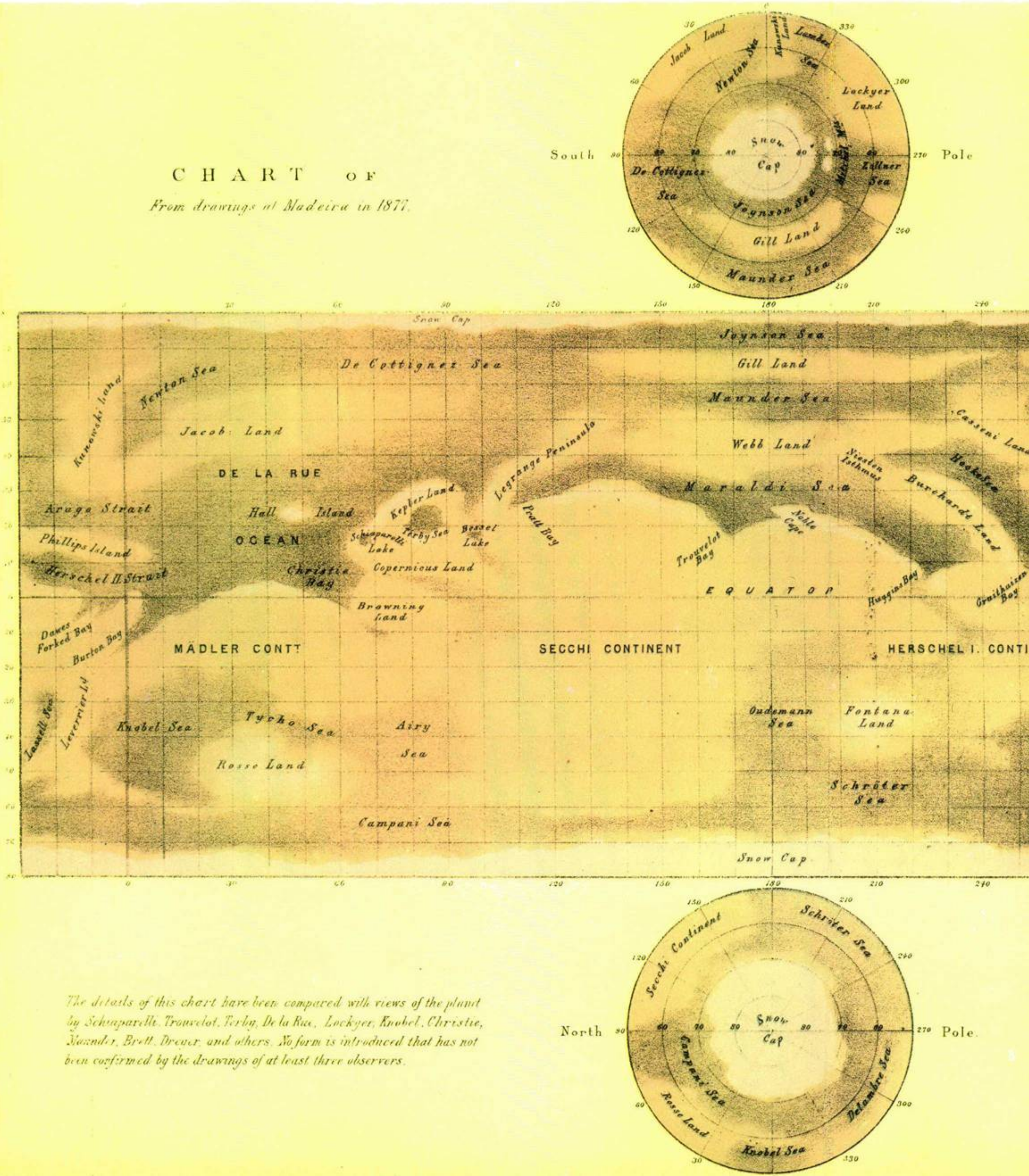
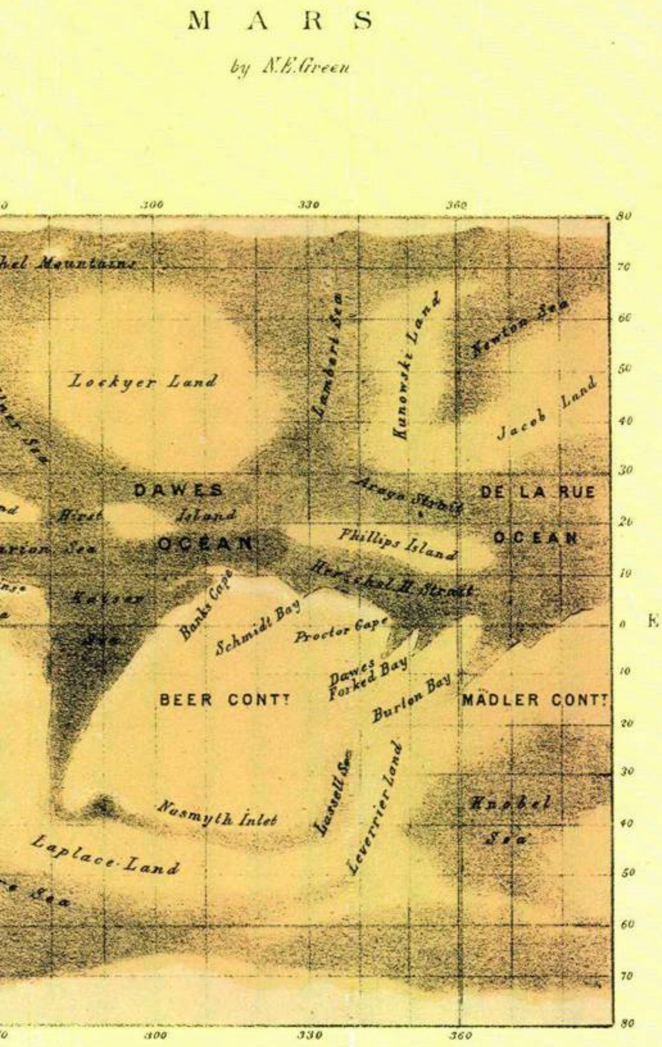


CHART OF
From drawings at Madeira in 1877.
South Pole
Jacob Land
Newton Sea
Kunowski Land
Lambert Sea
Lockyer Land
Snow Cap
De Cottignez Sea
Zöllner Sea
Joynson Sea
Gill Land
Maunder Sea
Snow Cap
Joynson Sea
De Cottignez Sea
Gill Land
Newton Sea
Kunowski Land
Maunder Sea
Jacob Land
Cassini Land
Webb Land
Lagrange Peninsula
DE LA RUE
Niesten Isthmus
Hooke Sea
Maraldi Sea
Burckhardt Land
Kaiser Strait
Hall Island
Kepler Land
Noble Cape
Terby Sea
Bessel Lake
Schiaparelli Lake
Phillips Island
OCEAN
Pratt Bay
Trouvelot Bay
Christie Bay
Copernicus Land
Herschel II Strait
EQUATOR
Huggins Bay
Gruithuisen Bay
Browning Land
Dawes Forked Bay
Burton Bay
MÄDLER CONTT
SECCHI CONTINENT
HERSCHEL I. CONTI
Lassell Sea
Leverrier Ld
Knobel Sea
Tycho Sea
Airy Sea
Oudemann Sea
Fontana Land
Rosse Land
Schröter Sea
Campani Sea
Snow Cap
Secchi Continent
Schröter Sea
North Pole
Snow Cap
Campani Sea
Rosse Land
Delambre Sea
Knobel Sea
The details of this chart have been compared with views of the planet by Schiaparelli, Trouvelot, Terby, De la Rue, Lockyer, Knobel, Christie, Maunder, Brett, Dreyer, and others. No form is introduced that has not been confirmed by the drawings of at least three observers.

the area formerly called Elysium is now Elysium Planitia (220 degrees west longitude, 28 degrees north latitude). The Martian valleys are treated differently and named after the planet Mars in various languages such as the Arabic "Al Quahira" Vallis (197 degrees west longitude, 20 degrees south latitude). The new names are shown on the Lowell Observatory Martian Albedo Features and Topographic Map. For their pronunciation and explanation, see the box on page **25** .

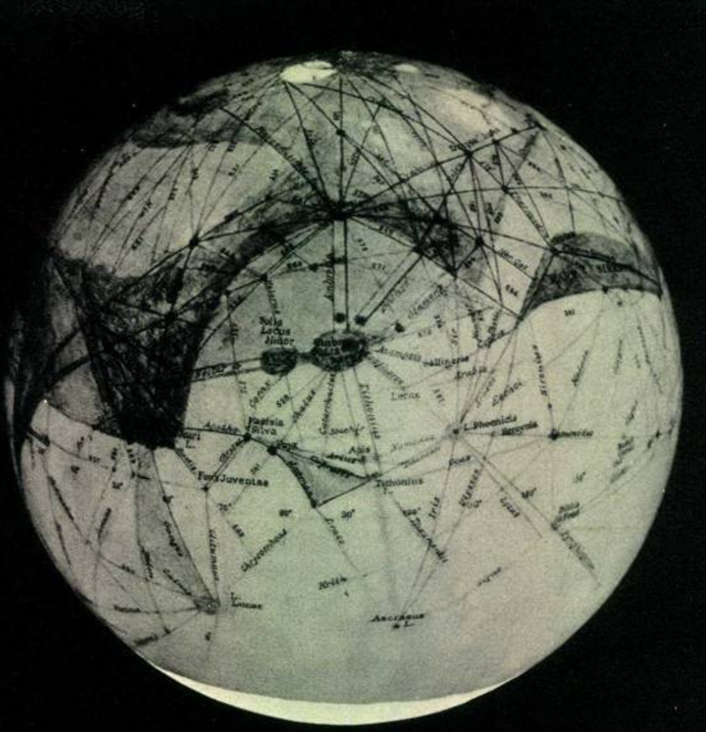

MARS

by N.E.Green

300
330
360
80
70
60
50
40
30
20
10
0
E
hel Mountains
Lockyer Land
Lambert Sea
Kunowski Land
Newton Sea
Jacob Land
DAWES
Island
OCEAN
Arago Strait
DE LA RUE
OCEAN
Hirst
Phillips Island
Herschel II Strait
Kaiser
Sea
Banks Cape
Schmidt Bay
Proctor Cape
Dawes Forked Bay
Burton Bay
BEER CONTT
MÄDLER CONTT
Lassell Sea
Leverrier Land
Knobel Sea
Nasmyth Inlet
Laplace Land

rthern portion of the chart is supplied from drawings made in 1873,
ay be considered provisional. The names with a few exceptions are
employed by Mr Proctor in his chart of Mars, adapted as far as
le to the recent observations. New names have been added by the
r where required.

HANHART IMP.



The globe of Mars as drawn by Percival Lowell in 1909 is cobwebbed with the now famous "canals." Although the canals turned out to be optical illusions, Lowell and his collaborators discovered many new features with the excellent Alvin Clark 24 inch refractor telescope on Mars Hill at Flagstaff, Ariz. Lowell's maps use the Schiaparelli nomenclature scheme and later Mars cartographers followed suit.

The largest Martian craters have been named after prominent deceased astronomers, telescope builders, rocket pioneers, science fiction writers, biologists, geologists, and others who have contributed to the study and lore of the red planet. About 200 such individuals have been honored — including the late, renowned planetary astronomers G. P. Kuiper of the Lunar and Planetary Laboratory, and Viking mission team biologist Wolf Vishniac, who met with accidental death while studying Martian life problems in the Antarctic.

A new **Atlas of Mars** in preparation by the United States Geological Survey consists of shaded relief maps at scales of about 400 and 75 miles per inch. The latter scale is about the same as some state road maps. Overprints of main telescopic features and elevation contour lines at one kilometer intervals will be superimposed on the shaded relief maps.

Today, the old and new feature names blend together on these modern cartographic tools ensuring an enduring history of the exploration of Mars.

Virginia W. Capen has studied and photographed planets for 15 years from several major observatories. She has contributed numerous works on planetary science to ***Icarus****, popular astronomy magazines and other publications. She has recently completed a book entitled* ***Martian Dictionary and Gazetteer****, which presents traditional Martian names and IAU approved nomenclature.*

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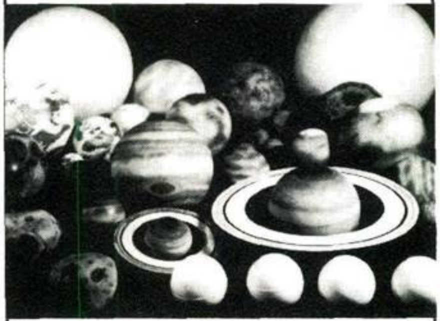

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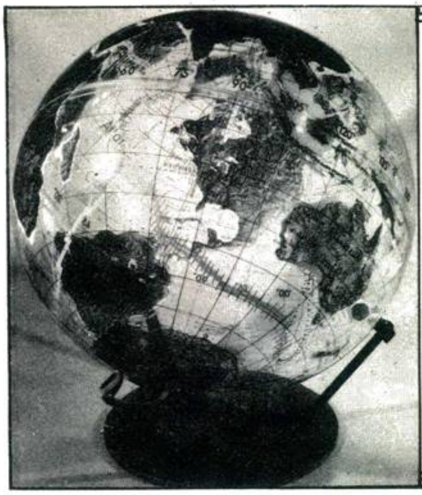

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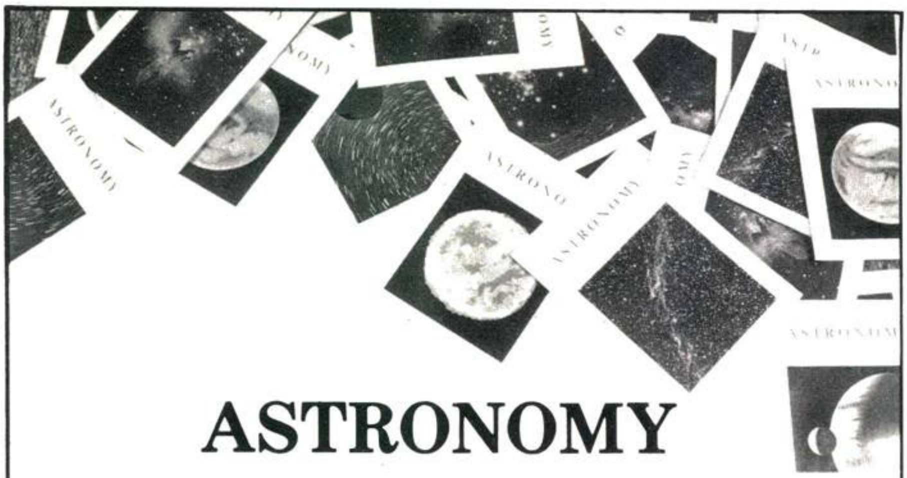

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Many readers continue to ask about the availability of ASTRONOMY back issues, but the majority blindly send us an order requesting issues we no longer have. For example, the October 1973 issue has been sold out for at least six months.

The following guide, which will be changed monthly, is designed to give you the most up-to-date information on the status of back issues. While they last, back issues are available for the cover price of $1.50 each (price includes postage).

When ordering, please clearly state quantity, volume, number, month and year for each issue (first issue was August 1973), and **include payment with your request.** If issues ordered are no longer available, unless you instruct us to forward a refund or substitute issues, we will automatically extend your subscription appropriately.

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Vol. 2, No. 1 - January 1974	**Short Supply**	**Vol. 3, No. 1 - January 1975**	**Available**
Vol. 2, No. 2 - February 1974	**Short Supply**	**Vol. 3, No. 2 - February 1975**	**Short supply**
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Vol. 2, No. 4 - April 1974	**Available**	**Vol. 3, No. 4 - April 1975**	**Available**
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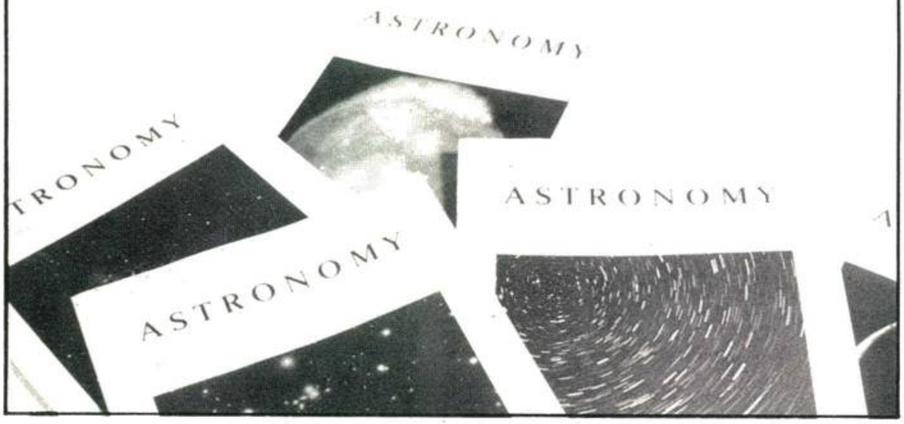

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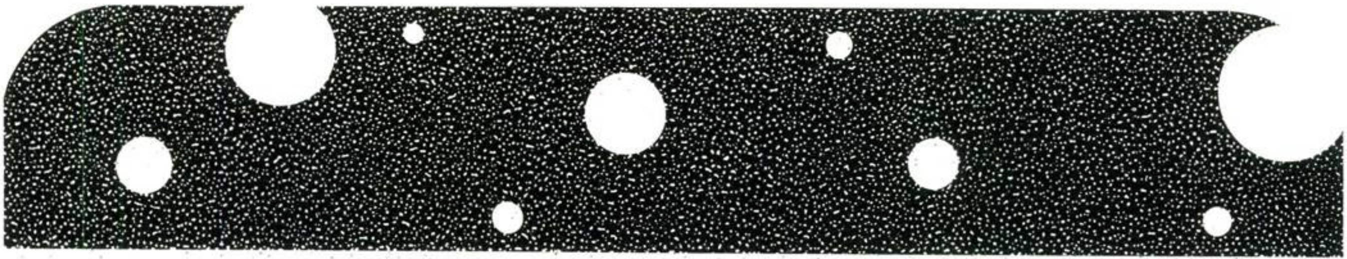


STELLAR FRONTIERS

X-Ray Astronomy

by

Gerrit L. Verschuur

Gone are the days when a dedicated astronomer sat for hours with eyes glued to the telescope — sketching craters on the moon, cataloguing new star clusters, or drawing nebulosities at unknown distances. No longer can one or two people spend years at one telescope and singlehandedly reveal wonders never before realized.

Today teams of scientists work together, designing and building sophisticated instrumentation. Rockets, satellites, and balloon-borne devices carry telescopes of shapes and functions never dreamt about 20 years ago. These telescopes are flown high above the atmosphere to probe the universe in regions where man's senses are totally useless. Up there, infrared and ultraviolet radiation, X-rays and gamma rays are streaming through space. The focus of the new research is to pinpoint the nature of the sources of this exotic radiation.

From this revolution toward probing the unseeable, X-ray astronomy was born. The X-ray is very short wavelength, high energy radiation that has found many practical uses in medicine and technology. But natural X-rays are alien to our everyday experience because our atmosphere totally absorbs them before they near the surface of Earth.

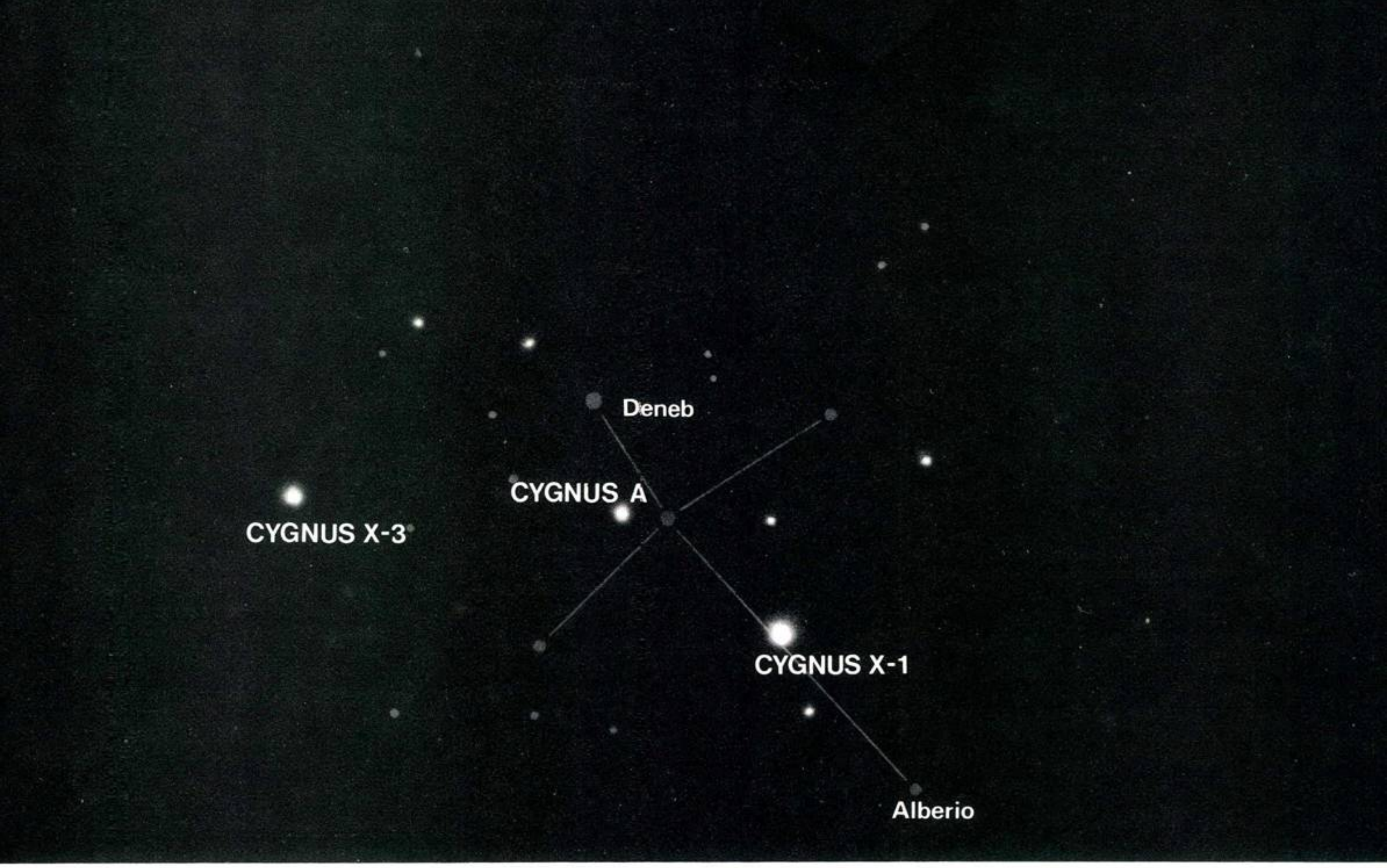
The new X-ray astronomy frontier brought teams of scientists and engineers together for devising ways of sending X-ray detectors above the protective atmosphere. First they flew balloons carrying only Geiger counters. Then rockets probed higher — but only for minutes at a time. In 1963, the first rocket-borne experiments discovered a strong X-ray source in the constellation Scorpius. So intense were X-rays from this location (named Scorpius X-1), that they were suspected of producing measurable changes in Earth's ionosphere.

Seven years later, X-ray detectors aboard the satellite Uhuru opened floodgates of new data. From Uhuru's accurate sensors, scientists found over 150 X-ray sources scattered throughout the sky. Since many of them clustered along the Milky Way, astronomers concluded that at least 80 X-ray locations were within our galaxy. The remaining sources seem to be spread randomly over the rest of the sky and probably are far from our Milky Way galaxy.

These suspected extragalactic points were studied closely and photos of the regions examined. Twenty of them have been identified as clusters of galaxies — groupings in which a hundred, sometimes a thousand, galaxies swarm in an enormous cloud. Eight other sources overlap positions of individual galaxies — often unusually active ones. Some X-ray-associated galaxies are exploding, and two or three X-ray spots are known to be quasars. At least 40 other extragalactic sources remain unidentified; no connection has yet been found between the energy point and an observable object.

What about those galactic sources lying along the Milky Way? The location called Cygnus X-1 is almost certainly a black hole, and Hercules X-1 marks a binary star system displaying periodic fluctuations in X-ray and light emissions. (Cygnus X-1 was described in detail in "Black Holes — Gateway or Grave?" in the February 1975 issue, and in "The Cosmic Abyss", March 1974. Hercules X-1 received special attention in Stellar Frontiers, October 1973.) At least 24 X-ray emitting binary stars are listed in the catalog of Uhuru sources — not all of them so dramatic in character as the above two. Five sources identify supernova remnants — the graves of dead stars. Four globular clusters also emit X-rays. That leaves a lot of X-ray sources unaccounted for. Perhaps the remaining 45 hide behind obscuring clouds of interstellar dust.

Cygnus X-Ray Sources



Artwork by Victor Costanzo

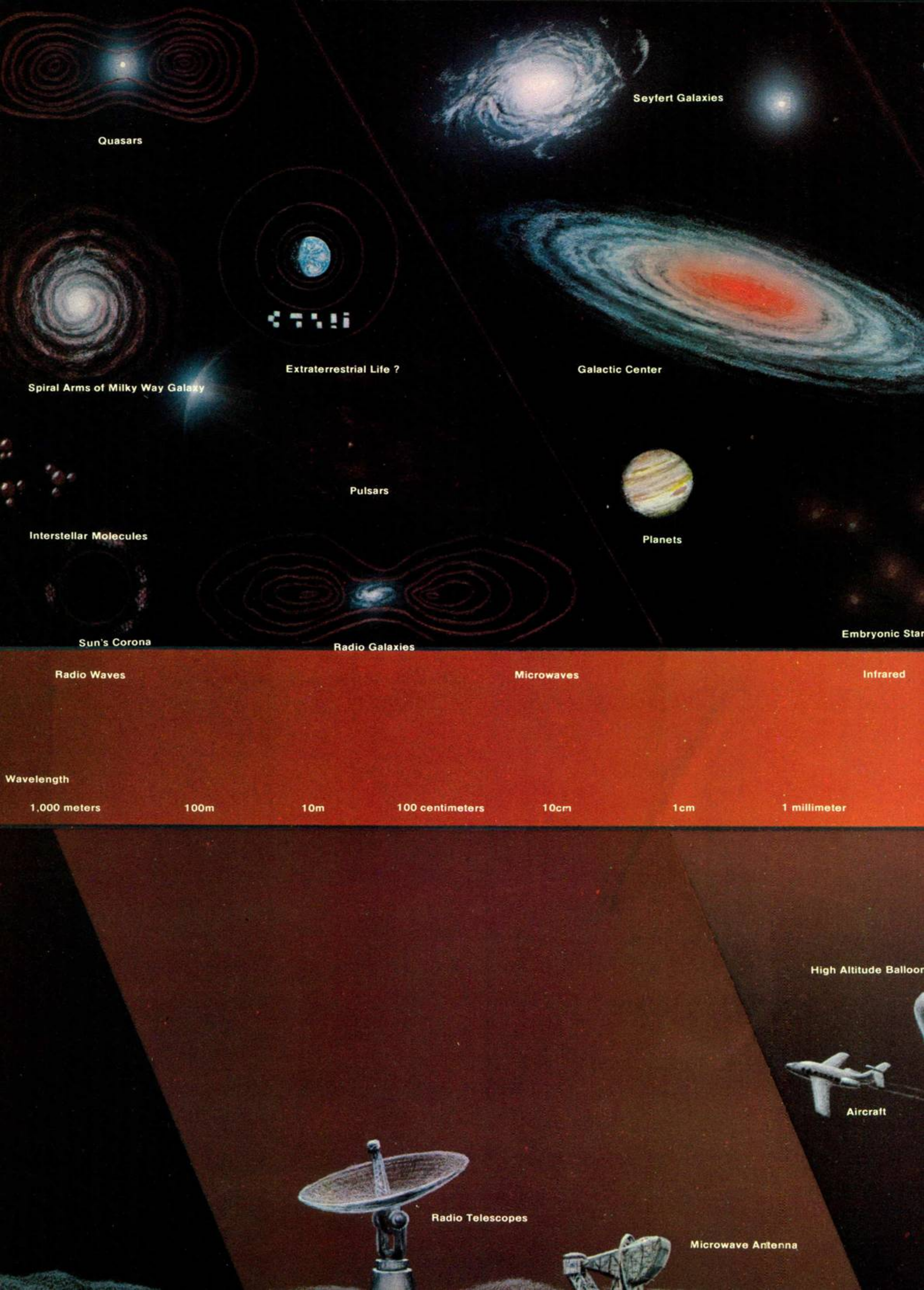
Through X-ray eyes, the constellation Cygnus vanishes — replaced by the ghostly glow of objects undergoing violent enough events for X-ray radiation emission. The most intense X-ray source in this region — Cygnus X-1 — appears with a brightness comparable to Sirius, the sky's most brilliant star at magnitude -1. On this arbitrary scale the strongest observed X-ray object, Scorpius X-1, would equal Venus' intensity. Likewise, the dimmest X-ray objects in this visualization have luminosities equivalent to the naked eye limit for visible stars. Astronomers believe Cygnus X-1 identifies a black hole.

Why do these various objects release X-rays? In the case of binary star systems, the black hole or neutron star component sucks in gas from its companion star. As the matter spirals into the gravitational whirlpool, it heats to a plasma of millions of degrees (hot enough for emitting X-rays). For matter plunging into a black hole, X-rays are the last signal that can escape before the plasma vanishes.

The Crab nebula, the ghostly remains of a star that was seen to explode in 1054 A.D., contains two X-ray sources. One is nearly the size of the nebula itself, and at the center lies a pulsating X-ray object or pulsar. High energy particles spiraling around the nebula's magnetic fields are energetic enough to release X-rays along with light and radio. X-rays appear to be coming mainly from the large visible filament of matter near the pulsar (see Stellar Frontiers, January 1975). The pulsar itself, that supercondensed core of the star that died in 1054, spins 30 times a second at the Crab's center. Some astronomers think that its dizzying rotation may provide energy for spewing off X-rays (plus light and radio), but the processes are not yet understood in detail.

Apart from small X-ray sources which are probably mostly binary star systems, there is a concentration of X-ray activity toward the galactic center (in Sagittarius). This special location is clearly not starlike. Measuring tens of light-years across and centered at the Milky Way's core, this source suggests that at our galaxy's heart, something very energetic is occurring — possibly an explosion, small by comparison with the distant X-ray sources and quasars.

In contrast to the mostly tiny X-ray beacons within the Milky Way, X-ray regions associated with clusters of galaxies are as large as the clusters themselves. This means that the radiation does not come from simply one galaxy, but something filling the volume of space between galaxies. Until that discovery, no one was sure if matter existed between galaxies; intergalactic space was thought to be empty. Today we know that is absurd. The formation of stars from interstellar matter cannot possibly use it all up; material must be left over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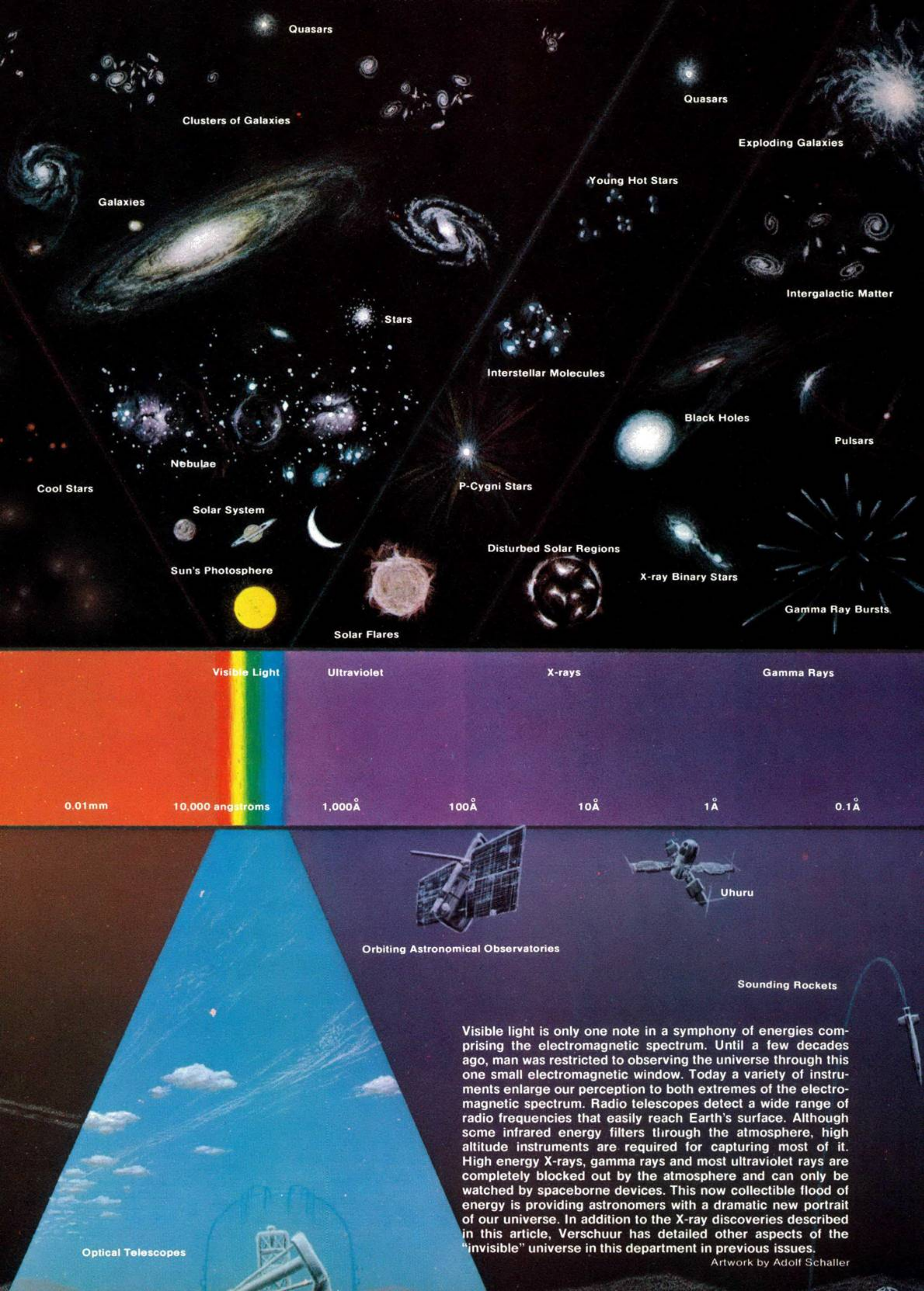
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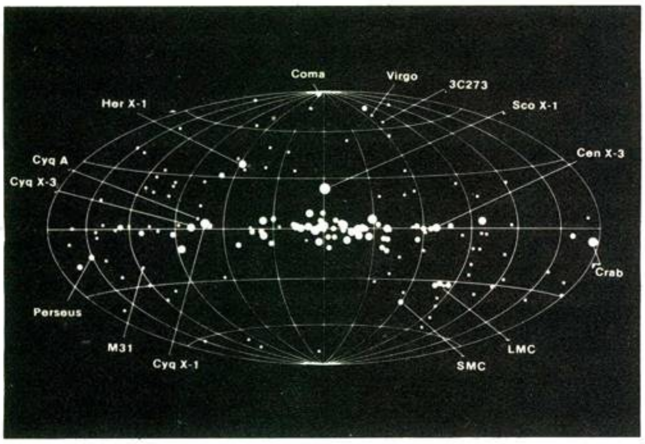
Visible light is only one note in a symphony of energies comprising the electromagnetic spectrum. Until a few decades ago, man was restricted to observing the universe through this one small electromagnetic window. Today a variety of instruments enlarge our perception to both extremes of the electromagnetic spectrum. Radio telescopes detect a wide range of radio frequencies that easily reach Earth's surface. Although some infrared energy filters through the atmosphere, high altitude instruments are required for capturing most of it. High energy X-rays, gamma rays and most ultraviolet rays are completely blocked out by the atmosphere and can only be watched by spaceborne devices. This now collectible flood of energy is providing astronomers with a dramatic new portrait of our universe. In addition to the X-ray discoveries described in this article, Verschuur has detailed other aspects of the "invisible" universe in this department in previous issues.

Artwork by Adolf Schaller



The location of X-ray sources based on observations by the Uhuru satellite are plotted on a galactic coordinates map with the plane of the Milky Way located horizontally across the center of the map. Much activity clusters along the Milky Way, indicating that many X-ray objects are within our galaxy. The brightest object in X-ray skies lies in Scorpius.

after star birth. So why the surprise at the X-ray indications of intergalactic matter? Mainly because all past searches employing radio and optical techniques have been unsuccessful. So far, intergalactic "starstuff" only becomes visible when astronomers extend their senses into the X-ray region.

The galaxy clusters in the constellations Coma and Perseus both emit X-rays. The Perseus cluster source centers on NGC-1275, a bright elliptical galaxy located almost at the cluster's center. Perhaps by some unknown process, NGC-1275 heats surrounding matter into radiating X-rays. Although the intergalactic gas must approach nearly 100 million degrees to produce X-rays, very little matter is required — about one atom in every 15 cubic inches of space. In such uncluttered volume, atoms can quickly speed up to high temperatures since few are slowed down by collisions with other atoms. However, the space between the galaxies in the Perseus cluster is so enormous that the total amount of gas is about four times the mass of the galaxies themselves.

Radio observations of NGC-1265 offer other proof for intergalactic matter. Data reveals a bright radio source at the galaxy's visible portion and a radio tail streaming behind it. Like the wake from a drifting sailboat, the tail may be a disturbance left behind as NGC-1265 plows through the intergalactic medium. The galaxy itself seems to be throwing matter outward as a result of some interior explosion.

The discovery of matter between galaxies means that the universe is more massive than thought. By measuring the total amount of mass in space, astronomers hope to learn if the universe is *finite* or *infinite*. Today we know that all galaxy clusters are rushing away from each other like material flung outward from an explosion. Will this expansion someday stop? A relatively massive universe would have sufficient gravity to brake the runaway galaxies, making it *finite*. But a lightweight universe would continue expanding forever, filling an *infinite* volume of space. Since the amount of visible matter in space falls 10 to 100 times short of making the universe finite, astronomers have been searching for invisible or missing mass. The X-ray glowing stuff in the Perseus and Coma clusters suggests that the universe is twice as massive as was thought 10 years ago. However, this remains far from enough mass to keep a lid on things.

Finally, on the largest scale imaginable, the entire universe emits X-rays. This remarkable discovery was made from Uhuru when its telescopes pointed at the moon! The satellite's detectors effectively count the number of X-rays hitting them every second. When they point at an X-ray star or a cluster of galaxies, the count rate increases — the number of counts being a measure of an X-ray source's strength. When the X-ray detectors point at the moon, the counts quickly drop — implying that the moon shields X-rays coming from distant parts of space. This always happens no matter where the moon is with respect to background stars and galaxies, meaning that the universe all around us radiates X-rays.

Astronomers currently believe that these background X-rays are ghostly signals still reaching us from a time shortly after the universe was created in the so-called big bang. In the mid-1960s, the "glowing embers" of that explosion were first detected. Although most of the radiation lies in the weak, microwave region of the spectrum, perhaps X-rays account for a small percentage.

During that ancient event, ultrahigh frequency gamma rays comprised most of the fireball's sizzling energy. So why is it diluted into microwaves and X-rays now? Because since then, primordial radiation has been expanding into space along with the rest of the universe. As the light from external galaxies shifts into lower, redder wavelengths, the farther those galaxies recede from us; fireball energy should similarly drop in frequency as distance increases. Since it was created long before galaxies, this radiation must be reaching us from extreme distances of at least 12 to 15 billion light-years — inplying great shifts in energy level.

Alternatively, the X-ray background may be produced by countless, very distant sources — all smoothed together by the relatively crude X-ray telescopes on board the satellite. This is unlikely, but only much more refined X-ray experiments will prove this beyond any doubt.

Through all evolution man has been almost totally blind — his vision restricted to one thin slice of the electromagnetic spectrum. Now spaceborne mechanical eyes are giving us almost godlike perspectives of objects and events invisible less than 10 years ago.

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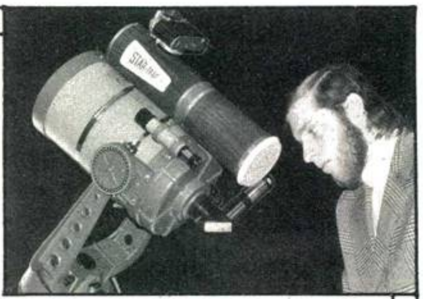

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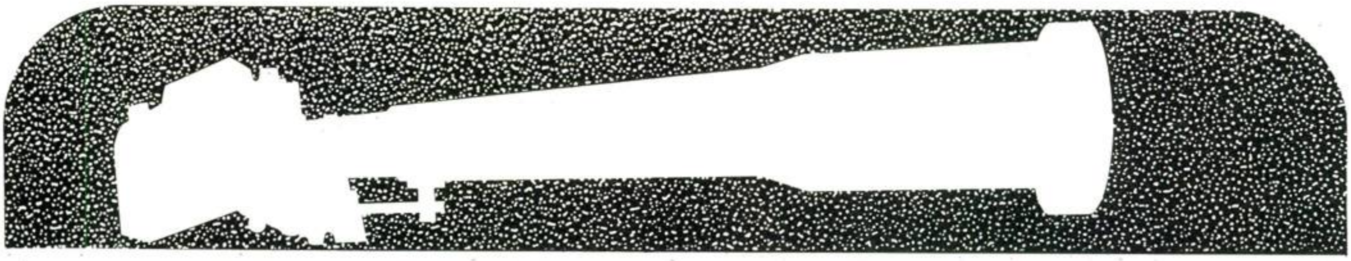


PHOTOGRAPHY IN ASTRONOMY

High Resolution Astrophotography

•

Improving Your Odds

by
Leo C. Henzl Jr.

It's a perfect night to "coax" your telescope a bit — clear and utterly calm, and Saturn is riding high overhead. At 450 power, the ringed planet spans a quarter of your eyepiece field. Cassini's division appears almost etched, and you can trace the Crepe's rosy glow completely around the inside edge of the ring. All in all, the view with — say — eight inches of aperture differs very little from the cover picture on the January 1975 issue of ASTRONOMY.

But that photo (considered the best color portrait yet of Saturn) was a professional effort with a 40 inch instrument. How can a backyard view from an amateur telescope match it?

The answer lies in the many odds stacked against the astrophotographer, amateur or professional — factors that conspire against capturing more than a portion of any telescope's visual resolution on film. What are some of these factors, and how might we go about stacking the odds more in our favor?

Seeing Conditions

Stable air overhead is the first prerequisite for any kind of high resolution work — be it photographic or visual. Although successful astrophotography generally comes with the expenditure of great amounts of film, it's pointless to expend either film or effort unless the atmosphere permits visual resolution near the limit for your instrument's aperture. Since most parts of the country afford only a dozen or so such nights annually, it is important to be prepared for good seeing when it does occur. Use those intervening turbulent nights to work out your exposures and image scales, so that your unsuccessful experiments occur when it doesn't matter.

Though we may classify seeing as "good" or "poor" on a particular evening, it is seldom totally one or the other all night long. Good seeing accompanies a stable pattern of airflow in the middle and upper atmosphere — dependent on large-scale weather phenomena — so there's nothing we can do along these lines except wait for proper conditions. (It helps to have a reserve "bag" of photo objects that don't require especially steady air; fine piggyback work, for example, is possible on almost any clear, moonless night.) Once the stage is set for good seeing, however, we can improve our odds considerably by scheduling our shooting for times when the air is likely to prove especially steady — usually when air and ground are near the same temperature. On a typical night, this occurs shortly after sunset and in the "wee" hours before sunrise.

The stark terrain of the waning gibbous moon is captured in this eight inch Celestron photograph exposed for 1/4 second at f/10 on H&W Control film. A companion close-up shot the same evening with a five inch telescope appears on page 52.

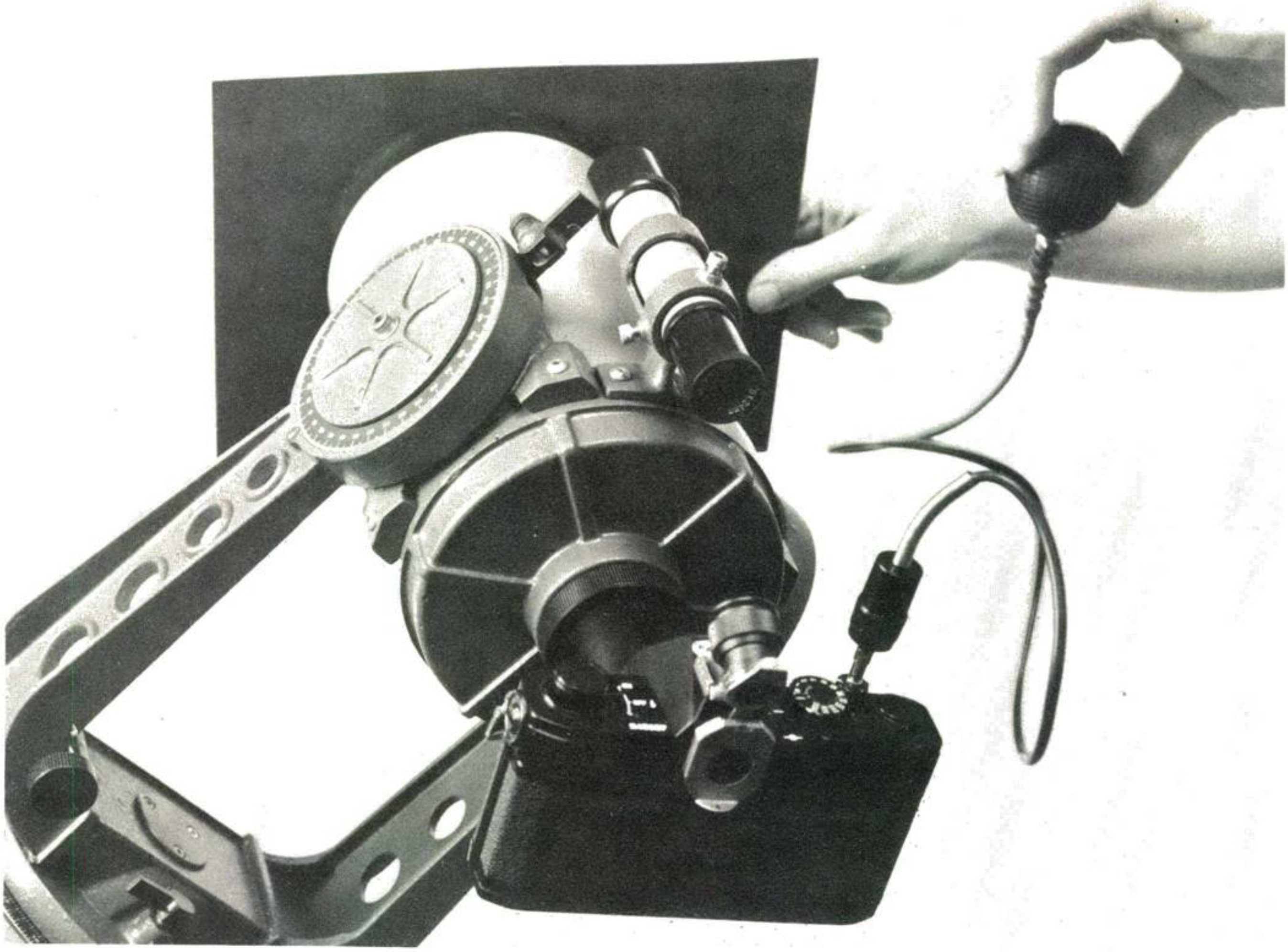
Photograph by Leo C. Henzl Jr.

During these periods when the tendency for local convections is reduced, a night of moderately good seeing often steadies marvelously for an hour or so. For daytime solar photography the same guidelines apply: The ideal situation is a midday clearing, after a cloudy morning has retarded ground heating.

Another factor related to seeing is the elevation of an object above your local horizon. The higher, the better — since your camera will "look" through a lesser blanket of haze and turbulent air. Objects of southerly declination are best shot when near your local meridian (due south at their highest elevation). Jupiter, for instance, has been quite unfavorably placed (for northern hemisphere observers) the past few years, thus necessitating photography within an hour or two of meridian transit — if at all. If you've been discouraged by recent attempts at photography of this planet, take encouragement from the fact that its orbital motion will carry it higher and higher for the next several years until it is placed as well as Saturn now — the latter being high enough for serious photography at least six hours a night. The moon's elevation also varies with phase and season. Your best chances for detailed lunar photos are as follows: crescent, summer; first quarter, spring; full, winter; last quarter, autumn.

Sharp Image Focus

Let's return now to that fine Saturn view we were describing and prepare for photography by inspecting the image through a 35mm single lens reflext (SLR) camera. If the camera is equipped with a "standard" focusing screen (matte texture overall, with a central "microprism" or split-image focusing aid), the view is far less inspiring than before. It may, in fact, be so dim and diffuse that your focus uncertainty amounts to 1/10 turn or more of your focusing knob. You may, of course, improve your chances for sharp focus by shooting many frames and varying your focus frequently over the zone of uncertainty. For bright, well-defined subjects such as lunar detail, an accessory



Illustrated here is the black hat exposure method described in the text. For exposures longer than 1/4 second, you can eliminate camera vibration completely by releasing your shutter with the card over, but not touching, your telescope's aperture. Allow a second or two for shaking to die; then time your exposure by uncovering and re-covering the instrument. Note the use of an "air release", which effectively isolates you from your telescope.

clip-on magnifier (like that shown) may reduce focus uncertainty to negligible proportions. For dimmer objects, the device helps indirectly if you first use it to focus the image of a bright star to the smallest possible point, and then use this setting for subsequent photography of planets. Here, though greatly reduced, the margin for error is considerable because the sensitivity of your test is still limited by diffusion and light loss inherent in your matte focusing screen. Given the limited probability of good seeing discussed earlier, it's important to make every frame count. So let's see what can be done to reduce focus uncertainty to relative insignificance.

The solution is simple if your camera is among the models of Nikon, Canon, Olympus, and others that feature user-interchangeable focusing screens. Though astrophotographers have been largely overlooked by camera manufacturers, it's fortunate that the focusing requirements for photomicrography (apparently a more popular endeavor) are identical: Focusing screens designed for use with microscopes also work beautifully with telescopes. Such screens are distinguished by having (either in their centers or overall) a perfectly clear area through which you focus on a bright, detailed aerial image — like that of an ocular — rather than the dim, grainy real image of a standard screen. Focusing is sure and positive; the zone of uncertainty is no greater than that of a high power eyepiece.

If your camera's focusing screen is fixed, it's still possible that the manufacturer or a camera repair shop can make a permanent screen change. An overall clear screen would render your camera unusable for normal snap-shooting, but among the offerings of many manufacturers is usually a matte screen with a clear center spot — a good compromise for photography of all types.

If neither option is possible and you're stuck with a standard focusing screen, you'll probably do better by learning to get along *without* it rather than *with* it. Roger W. Tuthill (whose advertisement appears elsewhere in this issue) offers a handy, inexpensive device that will enable you to achieve perfect focus independently of your camera's focusing system. This device, called an Astro-

Tule, is placed against the guides at your camera's film plane where a simple test — described fully in the Astro-Tule instructions — assures proper focus. The catch, of course, is that you must focus before you load and commence shooting — so it's important that you take care not to disturb your setting, and that your instrument be fully cooled to ambient temperature so that the focal plane stays put during your shooting session.

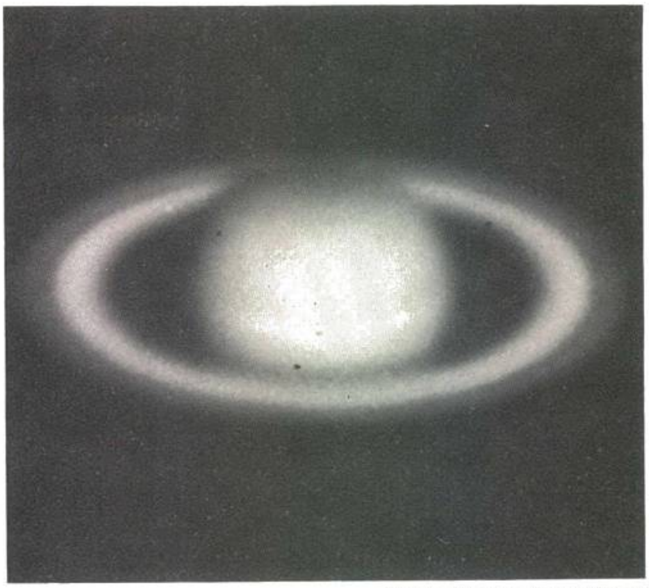
With a modest expenditure for an Astro-Tule or special focusing screen, there's no reason for any significant percentage of your frames to fall victim to inexact focus. And, as we'll see, there's enough else to go awry in any event.

Image Motion

Anything in your camera, telescope, and mounting system that causes or permits image movement relative to your film will compromise resolution in the same manner as the choice of too low a shutter speed for terrestrial action photography. Strictly speaking, poor seeing translates into anomalous image motion — but here we'll confine our discussion to mechanical factors. These include: 1) inaccurate polar alignment; 2) external forces such as wind or vibration from heavy local traffic; 3) irregularities in the telescope's drive system; 4) the action of the camera shutter and related moving parts, and 5) the photographer himself — through various inadvertencies of technique.

Remedial action for image motion due to external causes is a simple matter of avoidance — while exact polar alignment has been discussed in a prior article (see ASTRONOMY, January 1975). It is the other causes that are likely to prove most onerous.

A critical focusing magnifier easily clips onto camera accessory grooves and magnifies the central area of the viewing screen — usually from two to three power. The device helps to achieve sharp focus for bright objects such as the moon. The magnifier shown is a universal model, available for $8.95 from the well-known Spiratone mail order photo supply house. Most camera manufacturers also offer their own versions.



Photograph by James Rouse

Careful attention to details of technique netted Rouse this outstanding eight inch Saturn portrait. Cassini's division can be traced entirely around the ring — an elusive feature to capture on film with this size instrument, but not difficult to observe with smaller telescopes. The seven second exposure was taken with an eight inch f/7 Newtonian at f/80 on Kodak SO-410 film.

Let's assume that your drive system is working normally — that is, it's not suffering from the effects of any gross maladjustment in gear clearance or clutch tension. It is, then, completing one revolution in a period of approximately 24 hours. (We emphasize "approximate" because a typical error of 10 minutes or so, referred to 1,436 minutes in a sidereal day, is insignificantly small). This roughly "solar" drive rate is adequate for tracking all short exposure celestial subjects except the moon, whose rapid orbital circuit produces an apparent eastward motion relative to the fixed stars of about one hour of right ascension (or 15 degrees) per day. In terms of practical photography, this means that the moon will move about 0.5 seconds of arc eastward on your film for every second of time your shutter is open. Since the best amateur lunar photos can display resolution to one second of arc or better, it's essential that your drive system be slowed about five percent to a reasonably accurate "lunar" rate if you're to approach the photographic limits for a medium aperture telescope with any consistency. An electronic drive corrector will accomplish this. Some models offer the convenience of a switchable lunar rate, while others require observing the moon's average motion for a period of minutes under high power and adjusting the unit's calibration knob. If yours is among the latter, you'll save time by noting or marking the correct setting for succeeding photo sessions. (For more information about drive correctors, write DOAA Enterprises, 1912 W. 12 Mile Rd., Dept. AM204, Royal Oak, Mich. 48073.)

Assisted in special cases by a drive corrector, your clock drive's *average* accuracy is thus unlikely to pose any special photographic problems. Much more serious, in terms of photo mortalities, are the short term or *periodic* errors that cause your drive to run momentarily a bit faster or slow on a semi-regular basis. These irregularities result from necessary gear and bearing clearances and are thus inherent in any mechanical drive system — although they tend to be most pronounced in smaller portable telescopes, whose limited driven gear diameters put relatively few gear teeth in contact at any given time. Although a thorough prescription for all possible drive peculiarities is not within the scope of this article, here are a few guidelines:

(a) If the periodic error of your drive system seems especially severe, look into the matter of proper gear adjustment — as gear "pinching" or free wheeling is among the most common causes. Check your owner's manual or write to the manufacturer.

(b) Generally telescope drives run most smoothly when slightly "loaded" either into or against the direction of travel. In other words, you should not attempt to achieve perfect balance when counterweighting your telescope about its polar axis. Some drive systems work most smoothly when counterweighted so that the tube tendency is to swing eastward, others westward. Try both balancing procedures with your own instrument. The idea of such loading is to take up the necessary clearances against gear teeth and to keep them in intimate contact at all times. (Loading your telescope into or against the motion of the clock drive is usually accomplished by varying the position of the counterweight. Move the counterweight slightly higher or lower on the counterweight shaft than you normally would to make the telescope balance. In some cases counterweights may be added or removed to achieve the loading effect.)

If your subject requires an exposure shorter than 1/4 second (too brief for black hatting), a colored or neutral density filter in front of your camera can reduce effective film speed to the point where this technique is practical. A red (#25) filter was used for the lunar photo on page 40. The correct unfiltered exposure would have been 1/60 second for the gibbous moon, but the filter's 12 power exposure factor enabled the author to shoot at 1/4 second. Enhanced contrast is also a fringe benefit of shooting the moon through a red filter.

(c) Study the periodic characteristics of your drive over an extended time. Between intervals of "fast" and "slow" you'll find a transition period of correct drive rate. Learn to anticipate this period and use it for your exposures.

(d) Time your exposures so that you don't experience any significant percentage of mortalities due to obvious drive errors. This may mean some sacrifice of image scale for reduced exposure time, but the trade-off will probably be in favor of sharper photos.

(e) Disturb your drive as little as possible prior to and during exposure. Are you, for example, allowing enough time for gears and clutch to take up "slack" that may develop as you cock your camera? Are you using the common sort of metal cable release to trip your shutter? If so, it may induce drive slippage via its stiff, springy character when you start your exposure, or transmit body quiver and movement to your instrument while your shutter is open. An "air release" with a long, flexible hose is vastly preferable; squeeze the bulb gently so that you're surprised when the shutter trips — much like proper rifle technique.

The remaining cause of image motion stems from the mechanical operation of a 35mm SLR during exposure. Anything which has both mass and movement will set your telescope aquiver — and a

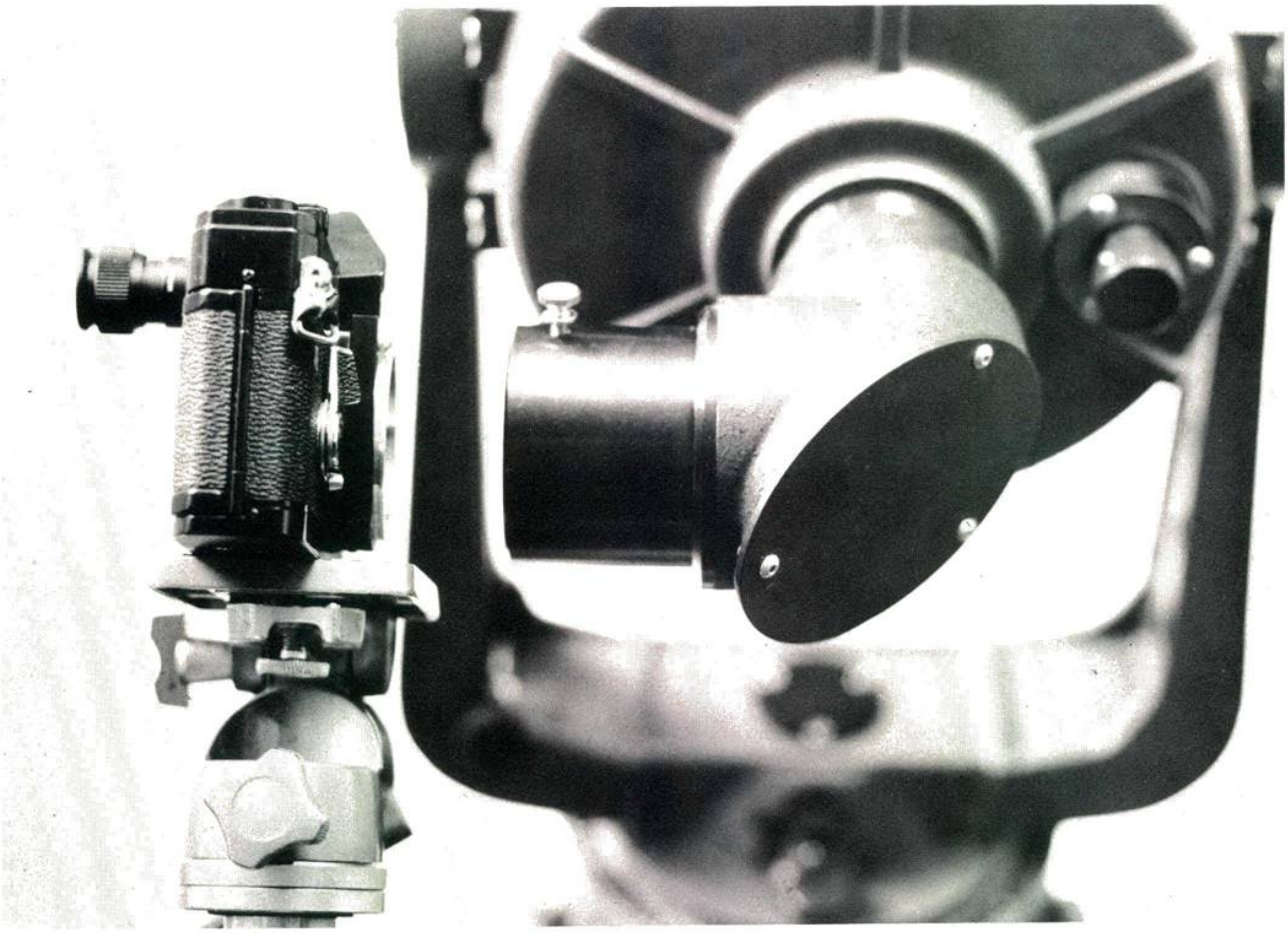
Used at the film plane of your camera, the Astro-Tule can reduce focus uncertainty to insignificance — regardless of your focusing screen type. This versatile little gadget also performs a variety of other useful tests, including a qualitative check of your telescope's optical system and precise measurements of magnification.

typical SLR is a very "busy" device indeed. Fortunately, it is possible to avoid the problem in many cases.

(a) For exposures of five seconds or more, it is probably pointless to take any remedial steps whatever. Unless your camera has the recoil characteristics of a cannon (the pun is strictly unintentional), and your telescope the rigidity of a wet noodle, the vibration induced will be of too short a duration to affect images adversely.

(b) For exposures from about 1/4 second to 5 seconds, use the "black hat" method. Set your shutter speed indicator for a time exposure ("T" or "B") and cover your telescope's aperture with black cardboard while you trip your shutter via remote release. Allow a second or so for vibration to fade, and then time your exposure by removing and replacing the card. Though it's difficult to time fractional-second exposures with this method, tests indicate that the most rapid possible motion of the cardboard will yield an equivalent exposure of 1/4 to 1/2 second. This is because the aperture is fully uncovered for only a fraction of the procedure's total time.

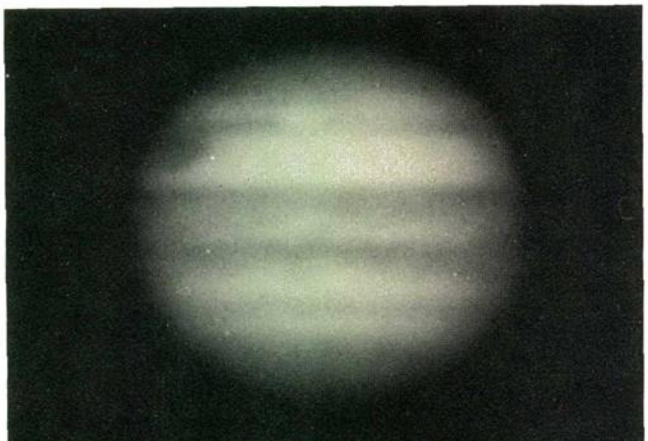
It is such exposures of less than 1/4 second that may present a vibration problem. How much of a problem will depend upon the design of your camera, the mass and rigidity of your telescope, and the shutter speed employed. Some homework with Earth based resolution testing will prove helpful here to ascertain what shutter speeds are to be especially avoided and what other remedial action may be necessary. Try shooting resolution charts or other detailed subject matter at a variety of shutter speeds (with your camera's mirror and autodiaphragm coupling prelocked if possible), and compare the results to black hatted or strobe lit exposures of the same subject. If the losses due to vibration are significant, try adding mass to your instrument (in the form of sandbags or barbell weights), and "footing" your tripod legs into the ground. If image degradation remains a problem with these shorter exposures, it may still be possible to sidestep the problem in several ways:



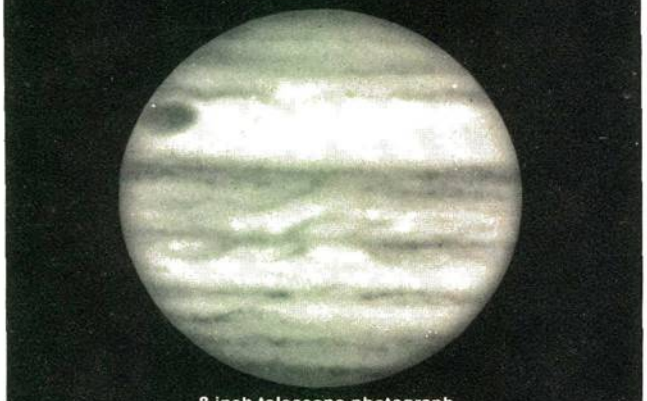
Though a bit more fuss, separating your camera and telescope is usually a better method of averting vibration with brief exposures than reducing film speed via filtration. All else being equal, the briefer exposure should net you the sharper photo. Note the Celestron 8's star diagonal is oriented so that the image is "approaching" the film plane, rather than whisking across it. The effect is a gradual loss of sharp focus instead of obvious image motion. Thus, the technique is also suitable for timing longer exposures — up to five seconds or so — but since the black hat method is so much easier, the primary benefit of camera isolation will be with fractional-second times. If streetlights are a problem at your shooting site, drape a black cloth across your instruments to prevent stray light from reaching your film.

(a) A subject that needs a 1/30 second exposure with a particular film will require a 1/4 second exposure if shot through an eight power neutral density filter. If your astrophotographic setup will accept such filters, consider using them to reduce effective film speed to the point where black hat timing is possible, or of using relatively slow films to begin with.

(b) Consider isolating telescope and camera by mounting the latter on a separate tripod, with its film plane facing the ocular holder. Though the camera itself will still shake, its much lower mass will produce vibration of higher frequency and lower amplitude — with correspondingly less effect on picture sharpness. To take full advantage of the method, rotate the tube of your Newtonian reflector or the star diagonal of your refractor or Cassegrain reflector, so that the focal plane is perpendicular to the direction of clock-drive travel (see illustration). In so doing, you keep your drive system working for you: Instead of flying rapidly across your field of view, your subject stays centered and gradually changes focus over a period of seconds. Otherwise your exposures would be limited to the relatively short times of an undriven instrument.



8 inch telescope view



8 inch telescope photograph

A fine eight inch Jupiter photo records about as much detail as a three inch refractor reveals visually. Photographs taken under the best conditions seldom capture more than 40 percent of a telescope's potential resolution.

Photograph by Leo C. Henzl Jr.. Artwork by Victor Costanzo

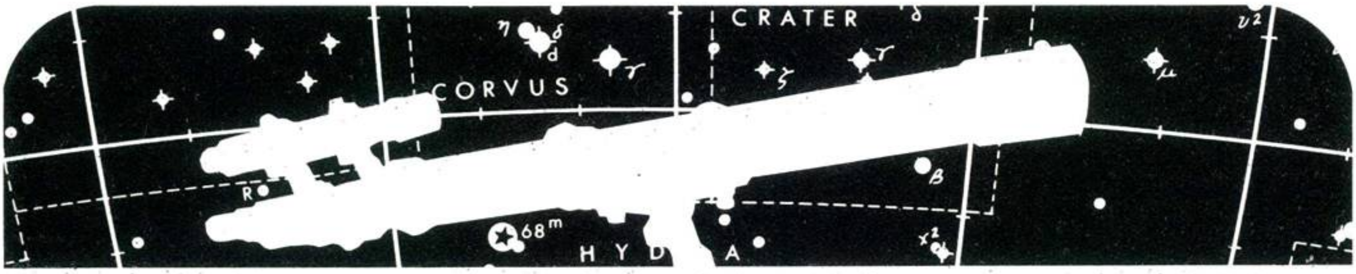
Inherent Limitations of Photography

If you could eliminate the effects of the odds discussed so far — seeing, focus and image motion — shooting perhaps from an absolutely stable platform in space, you would certainly improve your photos hugely. But even this wouln't enable you to capture 100 percent of your instrument's visual resolution on film because a certain amount of loss is inherent in the process of photographic imaging itself (as anyone who has employed resolution charts to test his camera lenses will realize).

Although some loss is inevitable, the reasons for essential losses are subtle. A sensible choice of film and image scale will help keep the non-essential losses — for gross emulsion characteristics such as speed, grain and resolving power — to an absolute minimum. If, for example, your preference is for a fast, relatively grainy film like Kodak Tri-X, it is important that you employ its high emulsion speed to project a fairly large image at the film plane of your camera so that the final print — at a modest enlargement ratio — isn't hopelessly grainy and low in contrast. Some photographers prefer this approach, while others favor the use of a fine grain film to project a relatively small image at the film plane — with greater subsequent enlargement in the darkroom. Both techniques can yield fine photos provided that one obeys the basic rule of proper image scale choice. The final choice is thus a matter for some experimentation of your own — and for a point of departure, you'll probably find the photo caption data from successful efforts by others to be your best guide.

Conclusion

It should be evident that a good high resolution amateur photograph is not a faithful representation of his telescope's visual performance, but rather a successful attempt (against considerable odds) to record an appreciable percentage of his instrument's potential on film. About 40 percent qualifies as an exceptional effort with a medium aperture instrument; that is, the best published eight inch planetary photos appear to show about as much detail as a skilled observer would see with a three inch instrument under the same conditions. To achieve this modest percentage, however, it is essential to perfect all details of technique within your control. Even so, there is yet another set of odds with which to contend — the relatively small percentage of frames where everything works according to plan, regardless of how careful you have been. If your experience is typical, 20 negatives of a given subject will net perhaps four or five worthy of close inspection or trial printing; the other 75 percent fall victim to seeing conditions, incorrect exposure, drive irregularities, emulsion scratches and a host of other ills. For this reason, if there is one overall prescription for improving your odds, it is to use lots of film when conditions permit and keep a large wastebasket handy in your darkroom! ◆



The Field of View

Do you use your telescope every clear night or only a few times a year? Either way, one of the most useful tables of information you can have is one listing the field of view of each of your telescope's eyepieces. The circle of sky that you see through your telescope is called the field of view, and the size of that field depends on the characteristics of your particular telescope/eyepiece combination. Since there are so many possible combinations you have to make the table for yourself.

Why have such a table? Here are some examples of its uses: You can determine which of your eyepieces will show the entire moon, or allow you to take in Jupiter and its most distant moons, or examine both components of the "double double" Epsilon Lyrae. A more practical use is the reverse: When you are observing something — anything — you know the area of the sky you are looking at. You can instantly judge its size because you know the distance from one edge of the field to the other.

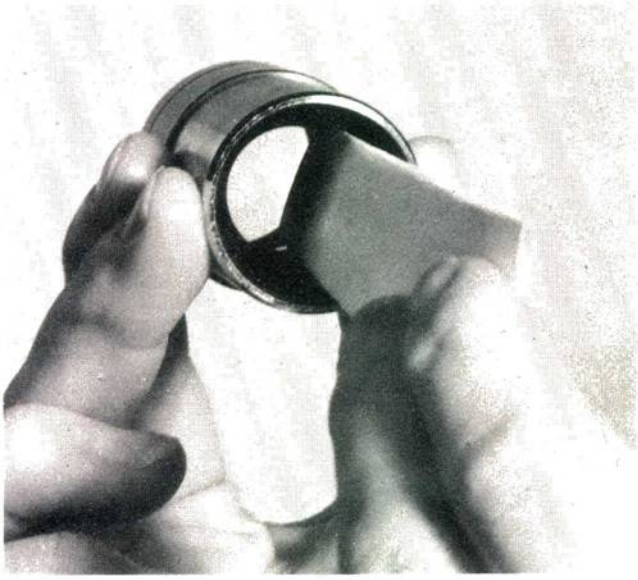
That's what field of view is — the width of that circle of sky that you see through the eyepiece measured (usually) in minutes of arc.

The standard sky measuring units are degrees when you are using the unaided eye or binoculars, minutes of arc for examining areas of the sky approximately the diameter of a telescope field of view, and seconds of arc when smaller sizes such as the diameter of planets or the distance between two components of a double star are considered.

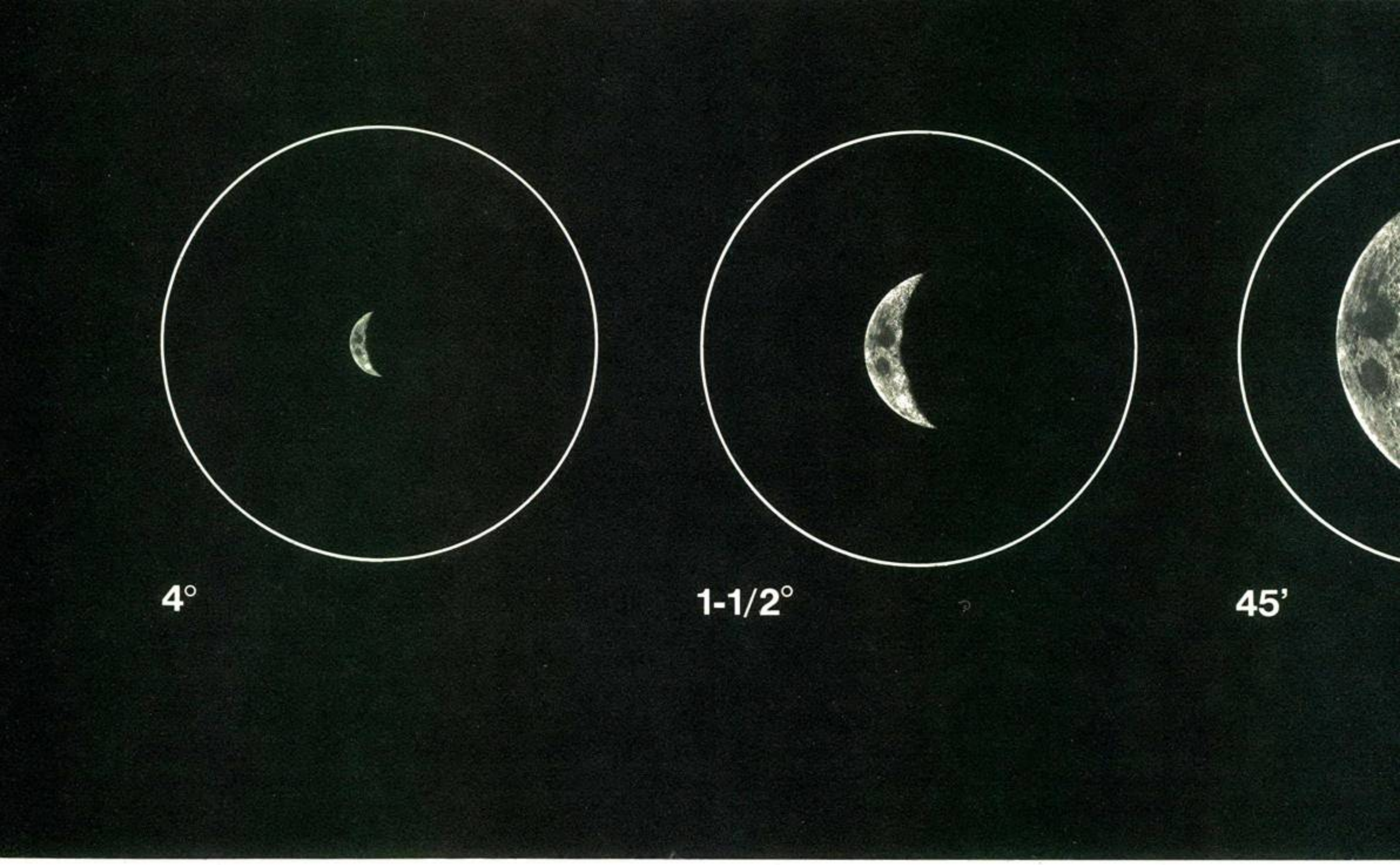
This system of degrees, minutes and seconds of arc is a measurement of angular width and is unrelated to the distance of the object. The basis of the measurement is the standard division of a circle (360 degrees). Thus, 1/4 of a circle — the distance from the horizon to the zenith (overhead point) — is 90 degrees. One degree equals 60 minutes of arc; one minute equals 60 seconds of arc.

The angular distance between Dubhe and Merak — the two stars in the Big Dipper that "point" to Polaris — is five degrees, while both the sun and the moon are approximately 1/2 degree or 30 minutes of arc in diameter. That means that it would take about 180 moons placed edge to edge to stretch from the horizon to the zenith. About 1/2 the diameter of the moon in apparent size is M-13, the great globular cluster in Hercules. The diameters of the planets listed each month in Sky Almanac give the scale of objects much smaller than the diameter of the moon or star clusters. All are less than one minute of arc in diameter.

In general, a smaller telescope will give a wider field of view with any particular eyepiece. To be precise, the field of view really depends on the focal length of the telescope and has nothing to do with its aperture. The same eyepiece will give identical fields of view with a three inch refractor or a six inch reflector of the same focal length.



This is a convenient way of measuring the unobstructed aperture of a field lens recessed into the eyepiece barrel. Fold a card until it fits the field stop perfectly. Then measure the card with an accurate ruler and apply the results to the formula on page 48. If the field lens and/or the field stop are near the end of the barrel you can measure directly without significant error.



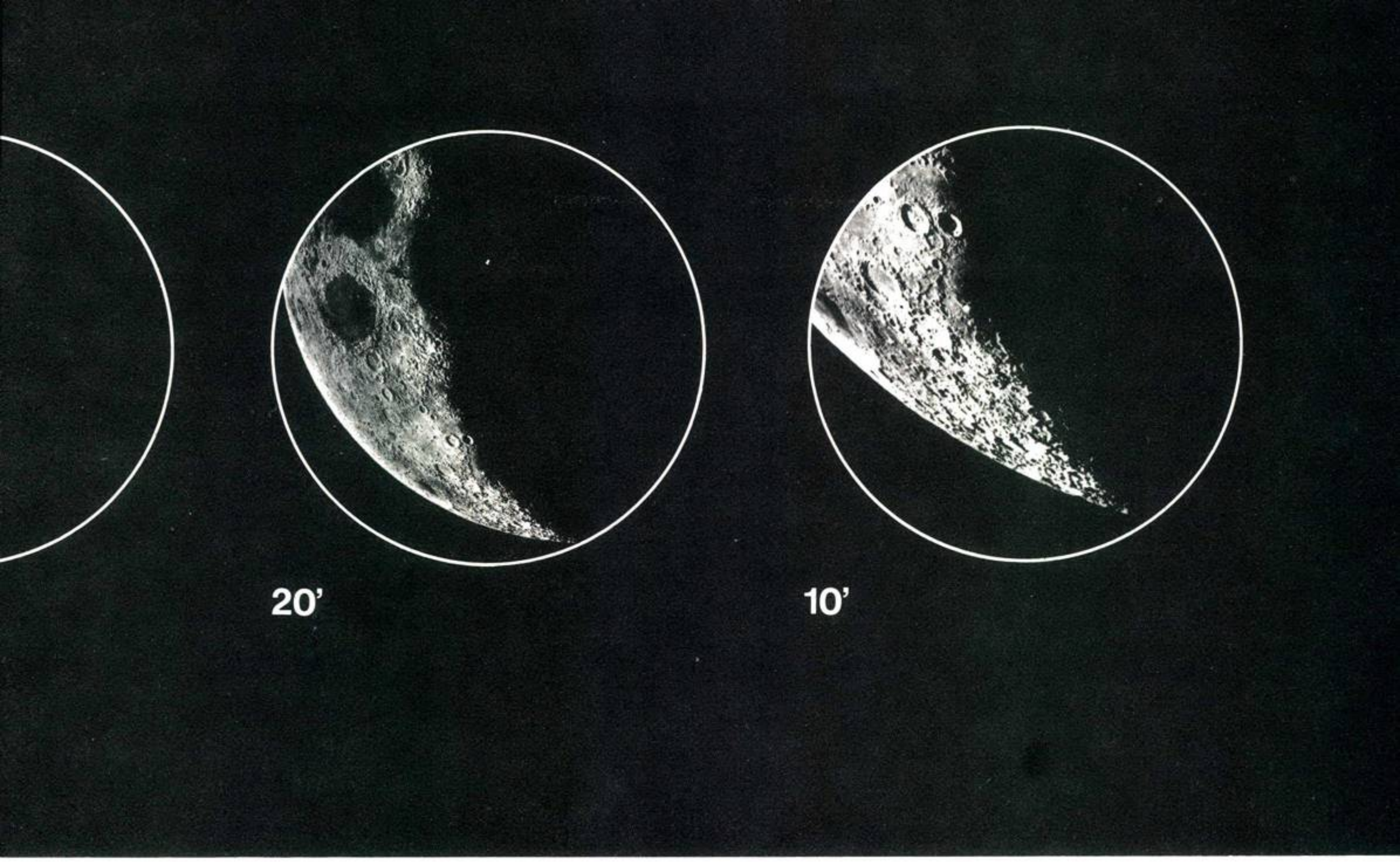
The manufacturer usually supplies the focal length of the telescope. It is expressed in inches or millimeters, or as an f-ratio to the objective. An eight inch f/7 telescope has a focal length of seven times the eight inch aperture — or 56 inches.

There are two ways to calculate the diameter of the field of view of any particular telescope/eyepiece combination. The first is an outdoor nighttime operation that will take just a few minutes of your time. Take each eyepiece in turn and select a star near the celestial equator (see Star Dome). Now let the star drift across the center of the undriven telescope field. Once you have determined that the star will bisect the field of view, move it just outside so it will drift in. As it drifts across, time the interval from appearance at one side (east) to disappearance at the other (west). This period in seconds, divided by four, is the diameter of your field of view in minutes of arc. For example: If the star takes 3 minutes 5 seconds to complete the field traverse, you simply divide that time (185 seconds) by four to get the field of view diameter of 46 minutes of arc. If the same eyepieces are used in another instrument, you should repeat the procedure and obtain a second table of field diameters.

The alternative method is almost as accurate and can be accomplished indoors on a cloudy night. All you have to know to begin is your telescope's focal length. Now, a complimenting number for each eyepiece is needed: the unobstructed field lens diameter; that is, the diameter of the lens in the opposite end of the eyepiece from the end that you look into. Each eyepiece has a different diameter field lens, and this can be measured by various methods to the nearest millimeter. (For these calculations we will be working in millimeters to avoid inch fractions. Inches can be converted to millimeters by multiplying by 25.4.) All you need to do is substitute the appropriate numbers in the formula in the box on this page. This should

Calculating Field of View

57.3	÷	focal length of telescope in mm	=	image scale in degrees per mm	×	measured field lens clear aperture	=	field of view
example:								
57.3	÷	732mm	=	0.078	×	19mm	=	1.48 degree field



The area of sky seen through a telescope is known as the field of view. Here we see the entire range of field of view sizes that pertain to the average telescope. The four degree field is typical of a finderscope. A 1-1/2 degree field is about the widest that any astronomical telescope can operate without severe losses in usable light transmission. Typically, a 45 minute field is achieved with a 20 to 40mm eyepiece and will be a common working viewing scale. Higher powers give smaller fields and more restricted views.

be a rapid procedure especially if you have an electronic calculator to help you with the arithmetic.

A third method of calculating field of view diameters that you may find suggested in some practical astronomy books is the least accurate. That method makes use of the eyepiece's apparent field of view as stated by the manufacturer. (The apparent field is the angular size of the circle of light you see when you hold the eyepiece to your eye.) The suggestion is to divide the apparent field of view by the magnification to achieve the actual true field of view through the telescope.

Suppose an apparent field of view of 70 degrees is quoted, and one divides that by the magnification to get the true field of view. The results are often far off the mark. The reason is that although eyepiece focal lengths (and therefore magnifications) quoted by manufacturers are almost always accurate, the figure for the apparent field of view is often incorrect — sometimes by a factor of 30 percent. The eyepiece marked 70 degrees apparent field of view may actually have only a 55 degree field of view. You can check this by following one of the two valid procedures outlined above and then multiplying the true calculated field of view by the magnification to get the apparent field of view, checking this against the manufacturer's specifications. In many cases discrepancies will be found. Somewhere back in the history of advertising, manufacturers developed the habit of quoting round figures for apparent field of view — but it's nothing to get excited about. The quality of manufacture is far more important than a crude estimate of apparent field diameter.

Some telescope users are "turned on" by the feeling of looking through a "porthole" to the sky — a feeling you may get using an Erfle type eyepiece. Indeed, sky views through such eyepieces are often spectacular. Before you invest in an ultra-wide field eyepiece, make sure your eyepiece drawtube will accomodate it. Obviously a drawtube accepting two inch eyepieces will ultimately permit wider field of view eyepieces than a 1-1/4 inch drawtube.

What combination do we recommend? Some very wide field eyepieces are available, but the images near the edge of the field may be so poor that not much is gained over a well corrected, narrower field eyepiece. (These aberrations were discussed last month.) The eyepiece to look for is one that gives you the widest high quality field with *your* telescope. Not only is it easier to find things with such eyepieces, but they are generally more comfortable to use.

SKY ALMANAC

Venus Dominates Spring Sky

This month we find Venus high and brilliant in the western sky at dusk and a moderate meteor shower attracting our attention. Saturn is somewhat fainter than earlier this year while the remainder of the bright planets are in unfavorable sky positions for convenient observation.

Venus

The brightest of all the planets is well placed in the evening sky this month and it can't be missed. At magnitude -3.5 early in April and -3.6 toward the end of the month, Venus is vastly brighter than any other starlike object in our skies. Look for the brilliant white steady light of Venus in the western sky as soon as the sun has set. As the sky grows darker, Venus becomes easier to see and soon is the dominant object in the night sky. The planet sets north of the west point about three hours after sunset — thus giving us a fine oportunity to examine it.

The telescopic observation of Venus is described in detail in this month's Gazer's Gazette. As the planet's distance from Earth decreases from 119 million miles on the 1st to 101 million miles on the 30th, we see its apparent size increase as viewed through the telescope. Its diameter during the month increases from 13.2 seconds of arc to 15.5 seconds while its phase decreases correspondingly from 82 percent illuminated to 72 percent. The reasons for the phase changes and tips on observing them are also given in Gazer's Gazette.

Between the 20th and the 25th of the month Venus will be within 10 degrees of Aldebaran in Taurus and will be dramatically contrasted with that star's reddish hue.

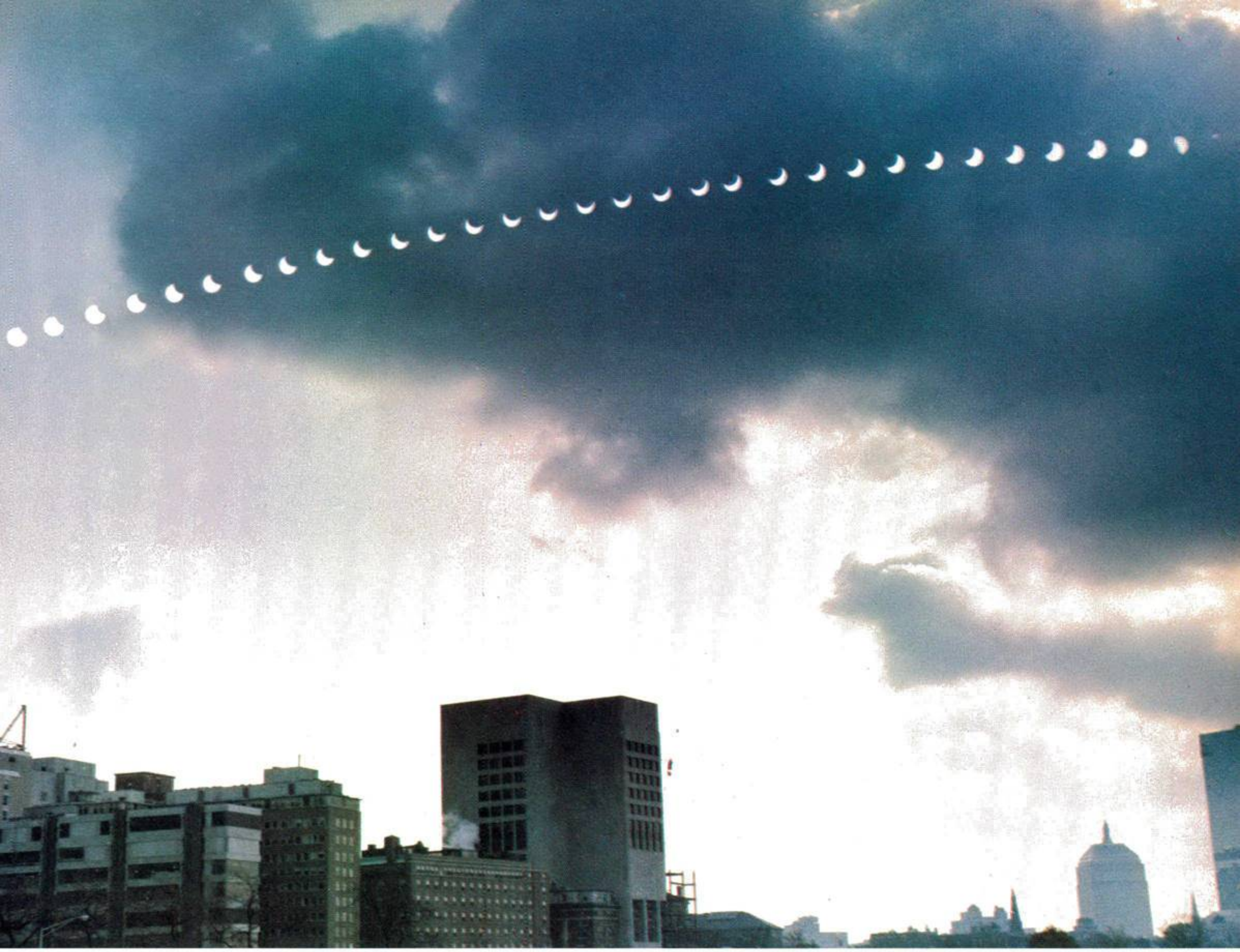
Saturn

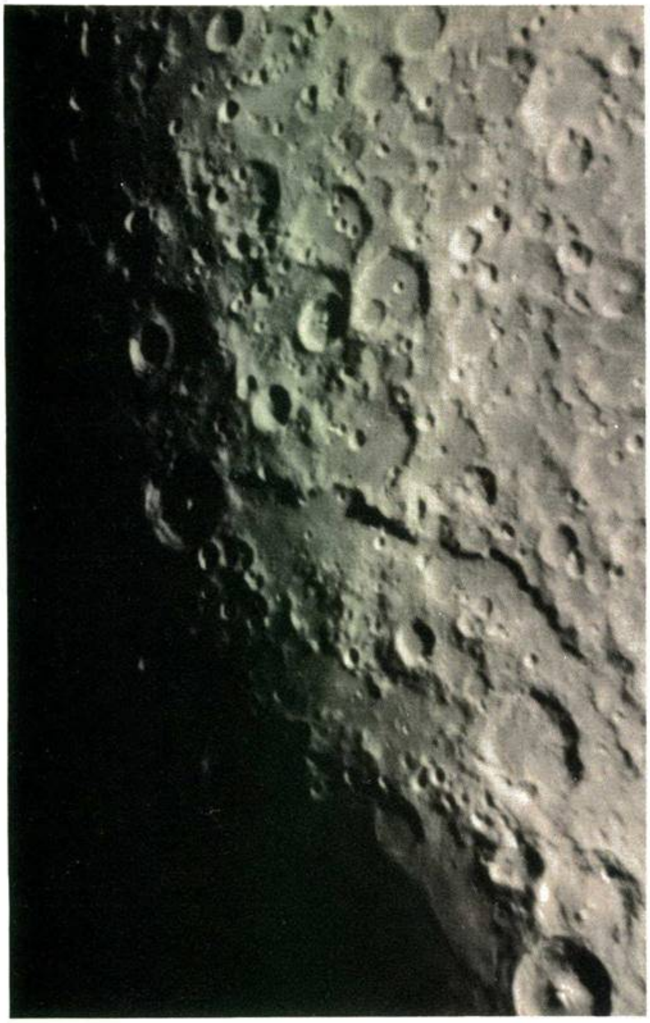
The planet that has lit up the already brilliant constellation Gemini for months is now actually significantly dimmer than it was last January. At that time Saturn was 750 million miles from Earth and appeared 46.6 seconds of arc in diameter from ring-tip to ring-tip. Its brightness at that time was magnitude -0.2. Now in mid-April, Saturn is magnitude +0.3 or only 60 percent of its former brilliance. The rings now appear 40.6 seconds of arc in diameter, and Earth and Saturn have increased their separation by 100 million miles.

What does all this mean? You now have to use 230 power on your telescope to see what 200 power would show last January. Although conditions are less than the excellent situation that we had then, Saturn observing is still nearly in full swing and because of the better weather maybe your views of the ringed planet will be equal to or even better than those obtained earlier in the year.

A sequence of exposures at five minute intervals captures the full duration of the Dec. 14, 1974 partial solar eclipse. A few passing clouds obscure the sun during the later stages of the event. Equipped with a 90mm lens, a 2-1/4 inch Mamiya RB-67 camera recorded the eclipse on Kodacolor-X film. Each 1/125 second exposure of the sun used a combination of an f/8 aperture and neutral density 5 filter. Clouds and the Boston skyline were added in an f/8, 1/60 second exposure. A very rigid tripod camera mounting is mandatory for this unusual type of eclipse photography. Photograph by Richard A. Pini

Just after sunset on Jan. 17, 1975, Venus and Mercury were only 1/2 degree apart and formed an interesting "double star" in the darkening sky. The exposure through a 50mm lens was 10 seconds at f/1.4 on High Speed Ektachrome. The photo was taken from Naples, Fla. Photograph by James K. Rouse





Photograph by Leo C. Henzl Jr.

The Altai Scarp (center) and the 67 mile wide crater Theophilus (lower right) are prominent features in this five inch Celestron telescope photo of the waning gibbous moon. The photo was a one second exposure using the black hat method on H&W Control film at f/50.

For those readers interested in specific statistics, Saturn's distance during April increases from 834 to 877 million miles from Earth and the outer ring diameter decreases from 42.0 seconds of arc to 39.8 seconds.

Mars

The red planet is slowly getting closer to Earth, improving its sky location for our inspection. During the month its distance decreases from 172 million miles to 157 million miles while its apparent diameter increases from 5.0 seconds to 5.5 seconds of arc. The planet is still too small for telescopes to distinguish surface markings — but at magnitude +1.2 it is less difficult to glimpse low in the southeast before sunrise than it was earlier this year. Mars will be improving its observing position all year due to its decreasing distance from Earth.

Jupiter

The giant planet is too close to the sun to be visible except at the end of the month when it may be glimpsed in the morning twilight, low in the southeast below and to the left of Mars. The only reason it may be seen through the twilight glow is its familiar brilliance (magnitude -1.7 at month's end).

Mercury

This is a month of transition for Mercury since it is swinging around the far side of its orbit and is largely lost in the sun's glare. However, the solar system's smallest planet is going to make its best showing of the year in May as described in Gazer's Gazette. We get our first glimpse of the performance on the last few days of the month when Mercury might be seen very low in the west, below and to the right of Venus shortly after sunset. Mercury will be very bright at magnitude -1.3 on the 27th, dropping slightly — but in better observing position — on the 1st of May at magnitude -0.9. On what day can you first detect Mercury in the twilight glow?

Uranus

The seventh planet is at its closest distance to Earth for the year on the 21st. That distance amounts to a colossal 1.62 billion miles or about 7,000 times farther away than the moon.

Lyrid Meteors

This moderate meteor shower occurs at its maximum force on the early morning of the 23rd, only two days before full moon. Thus the light of our satellite conspires to largely ruin this shower which can yield 10 to 15 meteors per hour at its peak. The moon sets at about 4:30 local daylight time on that morning and from then until sunup is the only time really worth trying to observe these meteors. Since this is such an inconvenient hour and short duration of observing opportunity, we must consider this a generally unfavorable situation; most observers will be content to wait for more favorable conditions. (For diehards: The meteors appear to radiate from a point between the constellation Lyra and Hercules — they're fairly fast moving meteors that generally leave persistent streaks.)

Eros

Now more than twice the distance it was during the historic January close approach, Eros is below 10th magnitude and fading fast. Many of our readers reported observing the small asteroid in late January when it appeared to pass near Pollux and Kappa Geminorum. Most observers said the asteroid appeared brighter than the predicted magnitude of 8.2.

The occultation of Kappa Geminorum by Eros was observed by only a handful of lucky amateur and professional astronomers near Hartford, Conn. The occultation track fell 200 miles southwest of the prediction given here in the January issue. This discrepancy is explained and additional details are given in Astro-News.

Observing the Inner Planets

Two of the five planets visible to the naked eye are closer to the sun than Earth. These inner worlds are naturally hotter than Earth, and their surfaces are totally alien to any conditions that exist on our planet.

Mercury, the closest to our star, is a 3,030 mile wide version of the moon. Its cratered surface was recently photographed by Mariner 10, and at a glance looks exactly like the moon. Temperatures there range from 800 degrees Fahrenheit during the 88 day period of sunshine on Mercury to -300 degrees during the depth of the night of equal length.

One of the major surprises to come from the space program revealed that Venus, although twice as far from the sun as Mercury, actually has a surface that is even hotter than the brutal midday heat waves on Mercury. Venus' dense atmospheric cloak of mainly carbon dioxide is 100 times as thick as Earth's. The temperature under this heat absorption blanket averages 890 degrees above zero. With savage heat on both worlds, virtually no atmosphere on Mercury and a stiflingly dense poisonous one on Venus, our visions of Earth type life on these worlds can only be embodied in the pure fantasies of 1950s science fiction movies.

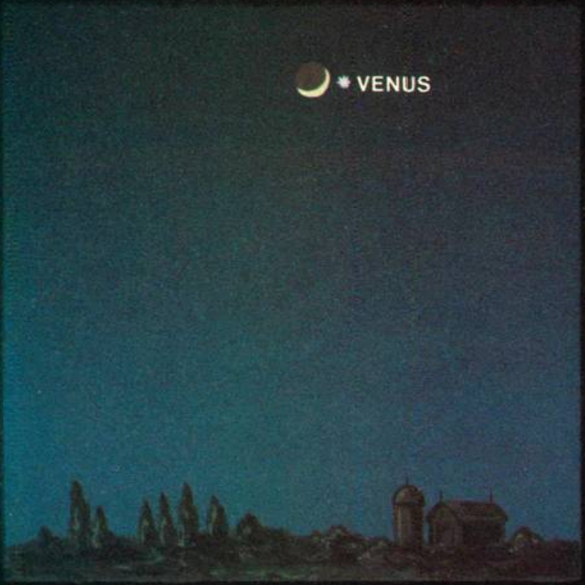
VENUS — OBSERVING DATA

Date	Magnitude	Phase (%)	Apparent Diameter (seconds of arc)	Distance (millions of miles)
April 2	-3.5	81	13.2	118.1
12	-3.5	78	13.9	111.9
22	-3.5	75	14.7	106.1
May 2	-3.6	71	15.7	99.5
12	-3.7	67	16.9	92.7
22	-3.7	63	18.3	85.5
June 1	-3.8	58	20.0	78.0
11	-3.9	53	22.1	70.6
21	-4.0	48	24.8	63.1
July 1	-4.1	41	28.1	55.6

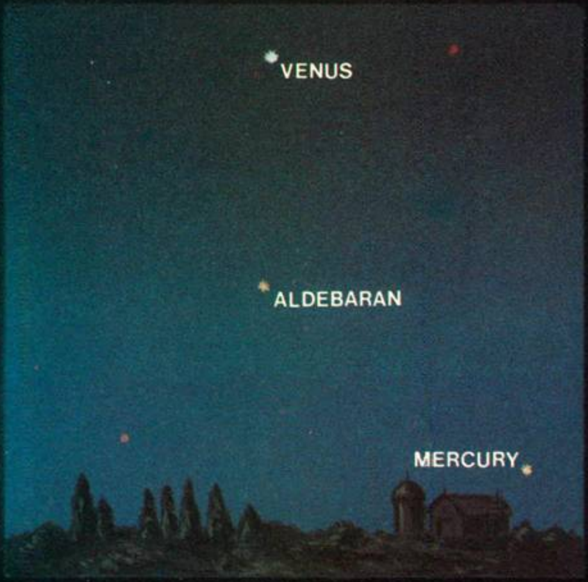
MERCURY — OBSERVING DATA

Date	Magnitude	Phase (%)	Apparent Diameter (seconds of arc)	Distance (millions of miles)
Apr. 27	-1.3	90	5.4	115.1
May 2	-0.8	77	5.8	106.3
7	-0.3	62	6.5	96.0
12	+0.2	47	7.1	85.5
17	+0.7	34	8.2	75.6
22	+1.2	23	9.3	66.9
27	+1.7	14	10.2	59.8
June 1	+2.3	6	11.4	54.6

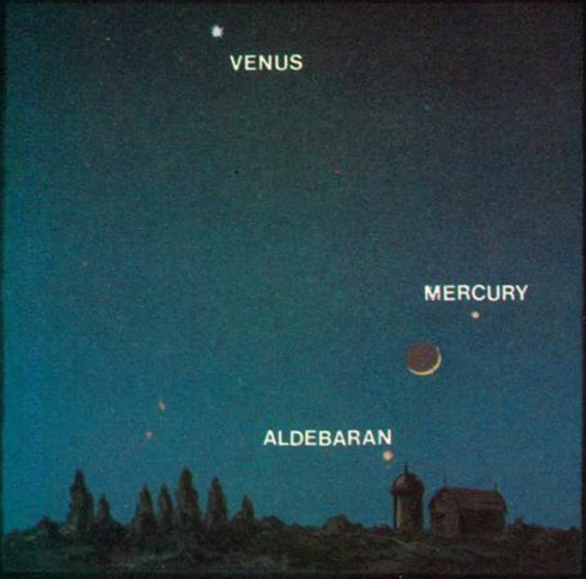
From our vantage point on Earth, observing Venus and Mercury is something like watching an



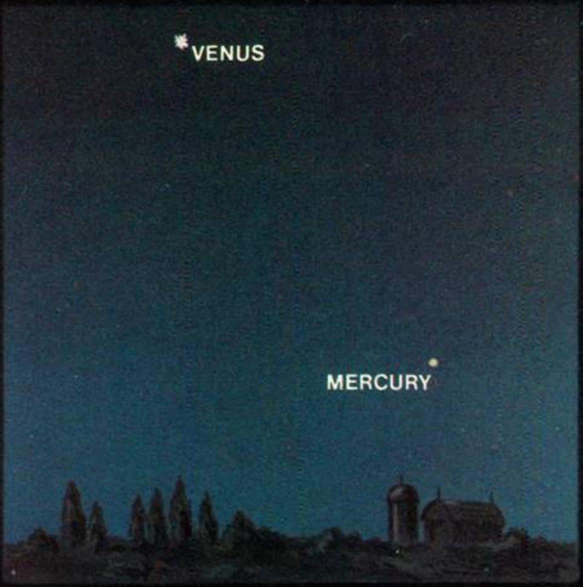
April 14


VENUS
ALDEBARAN
MERCURY

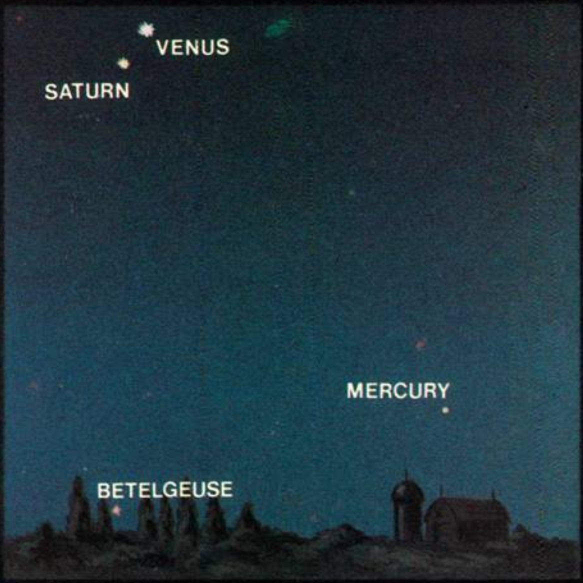
May 1


VENUS
MERCURY
ALDEBARAN

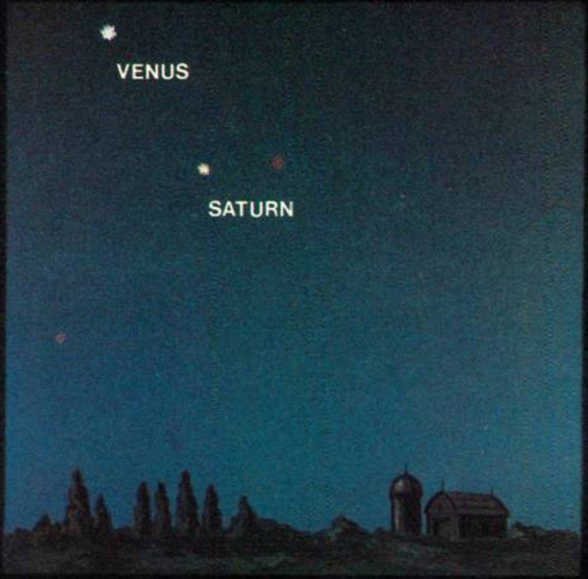
May 12


VENUS
MERCURY

May 17


VENUS
SATURN
MERCURY
BETELGEUSE

May 24


VENUS
SATURN

June 1

indoor track meet. Imagine yourself seated in the last row of the bleachers. You are watching two sprinters race around the track — only this is an unfair competition; one of the runners has the inside edge of the track while the other has the extreme outside. As you watch, the inside runner quickly outdistances his competition and roars from one side of the track around to the other in much less time than the poor fellow on the outer edge.

To make the analogy more complete, we have to put a "sun" at the center of the arena. We'll use some blinding spotlights that prevent us from viewing the competitors when they pass on the near side or the far side of the track. The only time we can watch them is when they are rounding the ends of the track. The athlete in the outer track is usually easier to observe — he moves at a steadier, seemingly slower pace and stays on one side of the spotlight longer than the racer on the inner rail.

We get the same kind of arrangement when we watch Venus and Mercury in the nighttime sky. Venus never gets farther from the sun than the "edge of the track", and Mercury barely gets out of the solar glare before zooming back into it again. This is far different from our best views of Mars, Jupiter and Saturn. These more distant worlds are on the opposite side of Earth from the sun when they are nearest, and at such times are ideally positioned for observation. But the best that Mercury and Venus can do is to get at their maximum distance away from the sun as viewed from Earth — a position called *greatest elongation.* Greatest eastern elongation (east of the sun) is the time we see these planets in the evening sky.

It happens that greatest eastern elongation of both Mercury and Venus is coming up in the next two months. Mercury will be at its maximum distance from the sun of 22 degrees on May 16; Venus will reach its maximum of 45 degrees east of the sun on June 18.

There are two additional factors other than the maximum separation from the sun that affect the viewing conditions for these planets — their brightness and the inclination of the ecliptic to the horizon. Based on brightness alone, these two planets are among the most luminous objects in the sky. Only the moon outshines Venus in the nighttime sky. Venus can be as bright as magnitude -4.4. By the end of June it will be nearly this dazzling at -4.0.

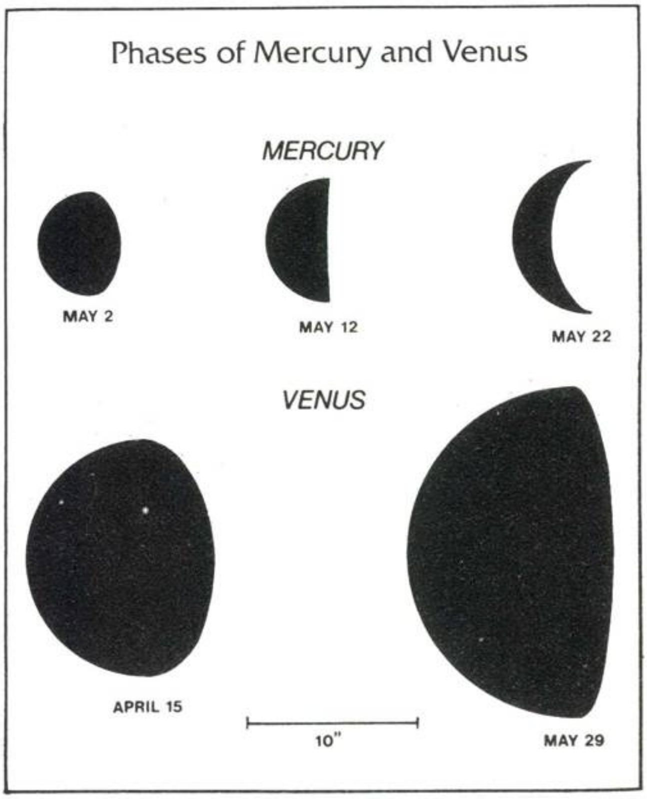
Mercury is usually about zero magnitude — about the brightness of Saturn or Capella — and although not as easy to observe as Venus because of its smaller orbit, it is a conspicuous object when it is well placed in the sky. This placement depends on the second of the two factors we mentioned above — the inclination of the ecliptic to the horizon. This concept is explained in the diagram on page 57 and has a great bearing on the visibility of these two planets — especially Mercury.

In the springtime the ecliptic is angled about 70 degrees off the horizon (for observers in mid-northern latitudes), while in autumn the angle is reduced to about 30 degrees. Although Venus and Mercury can be about the same distance away from the sun when at elongations at these two different seasons, by far the best time to observe both planets is in the springtime. In fact, the difference is so great that Mercury is virtually impossible to conveniently see in the fall evening sky.

Mercury's 88 day orbit around the sun makes it seem to move much more rapidly in the sky than Venus. The situation is diagramed on page 56 Here we see that Venus' slower motion around the sun means that it catches up with Earth much less quickly than Mercury. So in addition to being brighter and getting farther away from the sun, Venus also lingers in the sky for several months at a time whereas Mercury is visible for five weeks at the very longest — and usually less.

Telescopic Observation

Both Venus and Mercury are generally disappointments in the telescope compared to the boldly striped face of Jupiter or the unique beauty of Saturn's rings. In the case of Venus, this is be-



About 40 minutes after sunset during late April and May, the western sky will be illuminated by a variety of celestial objects forming, at times, striking configurations. Venus, because of its static position relative to the horizon is the key reference object throughout this period. Each scene is about 25 degrees wide with the arrows at the left side of each view marking the west point.

Artwork by Victor Costanzo

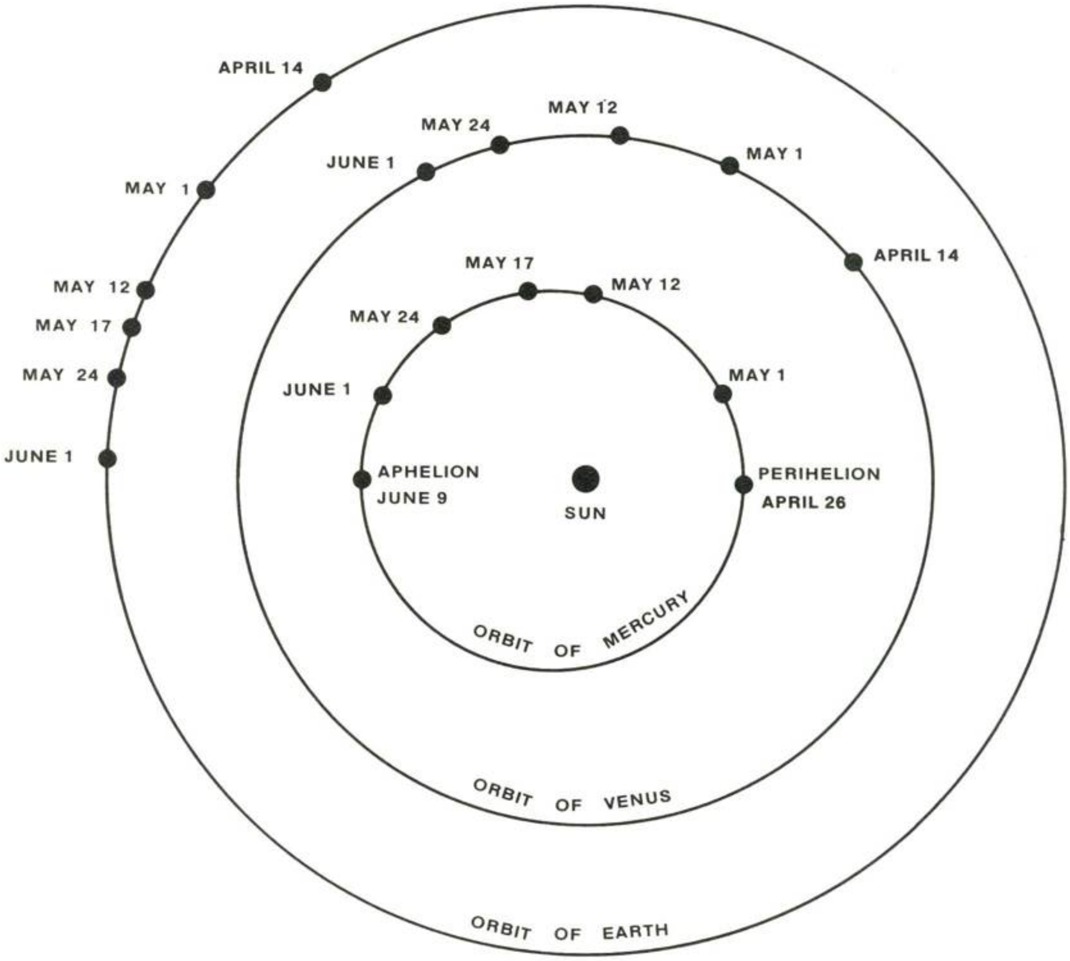
cause we are looking at a dense blanket of thick white clouds that are highly reflective and appear essentially uniform in brightness. Generally, the phases of the planets are the only thing that can be made out — sometimes we are looking at more nighttime side than at other times.

The phase is expressed in a percent. For example, on the 1st of May Venus' phase is 72 percent — which means that from Earth we see 72 percent of the planet illuminated by the sun; the rest is in darkness. Mercury also has phases, although because it is a smaller planet and farther away from us they are more difficult to detect.

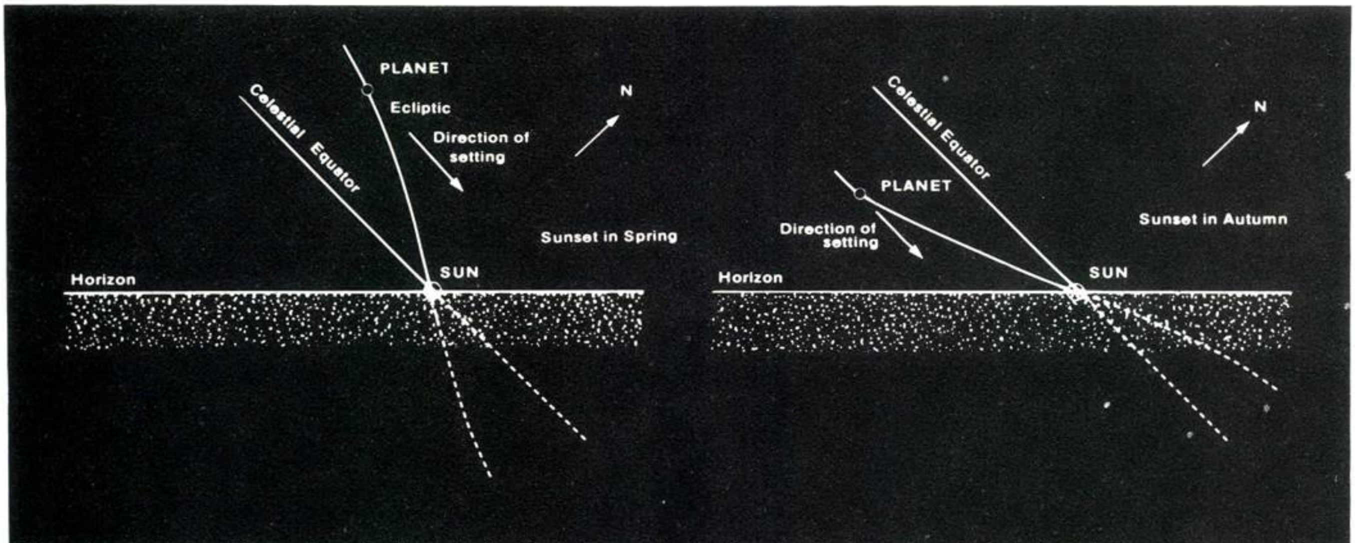
Depending on Venus' distance from Earth and the sun-Venus-Earth angle, the planet seems to vary tremendously in size as it goes through its cycle of phases. When it is far from us (near the other side of its orbit), we see the planet nearly fully illuminated. But because of its distance it appears quite small — about 10 seconds of arc in diameter. As Venus swings around and gets closer to Earth the phase decreases, but the diameter increases until it is a thin crescent slice 60 seconds in diameter.

It takes several months for Venus to run through from one of these extremes to the other. That period began last January and will end with the thin crescent in August. Mercury, however, goes through the same sequence in a period of just over a month. This compressed period of observability and phase change means Mercury observers must use every opportunity to telescopically observe the planet during its period of visibility.

The phases of Venus are much easier to distinguish than Mercury's. Its larger size (actual diameter is 7,525 miles compared to 3,030 for Mercury), greater distance from the sun and nearer approaches to Earth combine to make it an easy telescopic target. When Venus is a crescent of 15 to 30 percent illumination, even rigidly held good quality binoculars can be used to distinguish that the planet is not spherical or a point source. A 2.4 inch refractor should be capable of revealing all but the gibbous and full phases of Venus. Tele-



This diagram illustrates why Venus and Mercury will both be in excellent positions for observation in late April and May 1975. Using a protractor you can determine that Mercury will be about 22 degrees from the sun in mid-May as viewed from Earth. Compare that to the 15 degree separation on May 1 and June 1. You can also scale the distances between the planets and calculate their phases. The dates listed here are the same ones used in the illustration on page 54. Aphelion and perihelion marked on Mercury's orbit indicate the planet's respective far and near approach to the sun.



The planets always keep close to the ecliptic (the plane of the solar system) as they orbit the sun. Because of the tilt of Earth's axis, the ecliptic is sometimes angled well above the horizon (spring) or close to it (autumn). For this reason Mercury and Venus are best seen on spring evenings. The reverse situation exists for southern hemisphere observers.

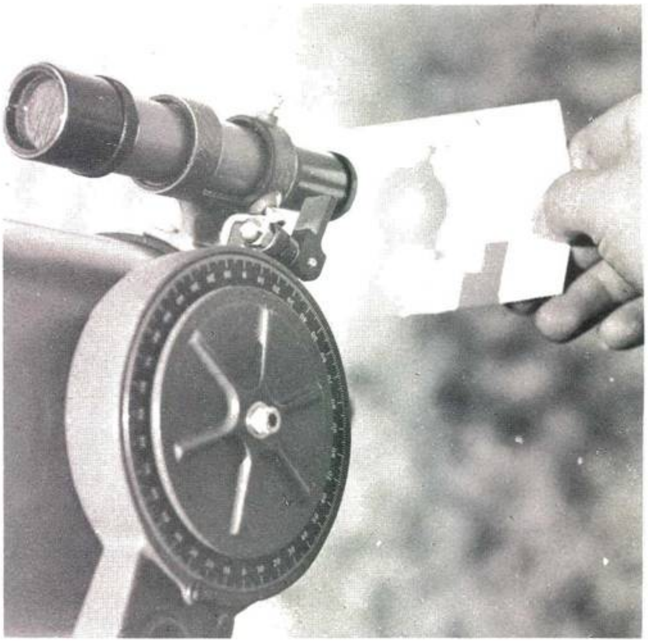
scopes of three inches or greater aperture are sufficient to follow the entire cycle of Venusian phases. Experienced observers have used three inch refractors to discern most of the phase cycle of Mercury, but larger instruments make the task less frustrating.

Observation of both inner planets — Mercury especially — is plagued by our own atmospheric turbulence that inevitably exists near the horizon. The disappointing aspect of this is that the darker the evening sky becomes following sunset, the closer Mercury and Venus descend toward the horizon. In addition, both planets are so bright (per unit of surface) that it really isn't necessary to telescopically examine them in dark skies. In fact, such conditions are undesirable.

The best time to conduct your Mercury and Venus observations is as soon after sunset as possible to avoid the turbulence and excessive contrast later in the evening. For Venus, this won't be very difficult since it is bright enough to be located with the unaided eye within minutes after sundown. (Sharp eyed observers can spot it in sunlit skies.) Mercury presents more of a problem. It would be best if we could catch it as far above the western horizon as possible, but it is not bright enough to be visible with the unaided eye until at least 20 minutes after sundown. Those 20 minutes represent a golden observing period squandered.

How, then, can we find little Mercury in the bright sky at sunset? One possibility is to sweep the area below and to the right of Venus using binoculars or a 40mm or larger finderscope. A second possibility is to offset from Venus using your telescope's setting circles (if it is so equipped). With the telescope approximately polar aligned (a rough guess will usually do since it will be too bright to see Polaris), offset the amount of right ascension and declination from Venus to Mercury using the table on page 58. This procedure should bring Mercury into the finderscope field of view. If it does not, your polar alignment is too far out and you will have to resort to the less effective sweeping method.

To observe Mercury and Venus even farther from the horizon you may want to try full daylight telescopic study. With both planets high in the sky after 2:00 p.m. local time, this strategy is pre-



To use setting circles to locate Venus and Mercury, the offset method is easiest. Alignment on the sun, the first step in the procedure, can be accomplished by centering the solar image in the finderscope shadow. For finders over 30mm aperture use tracing paper or some semi-opaque filter to prevent possible damage to crosshairs. Keep the main telescope's objective covered for this solar setup.

OFFSET FROM SUN TO VENUS

	R.A. Offset East	Dec. Offset North
April 1	2^h09^m	12.6°
10	2^h20^m	12.5°
20	2^h33^m	11.3°
30	2^h45^m	10.7°
May 10	2^h57^m	8.1°
20	3^h07^m	5.2°
30	3^h14^m	2.1°

Finding Venus by offsetting from the sun requires a telescope with setting circles. Move the telescope the required right ascension east and declination north and Venus should be visible in the finder. Interpolate for dates between those given here.

ferred by experienced planetary observers. The setting circle offset procedure is used — only this time, Venus is located by offsetting from the sun. This procedure is perfectly safe if you cover the main lens of the telescope and use the finder to center the solar image as shown in the photo on page 57. Now offset in right ascension and declination to Venus and, after examining that planet, offset to Mercury. (Daytime observing will only be satisfactory if you have a clear, deep blue sky. Both planets fade "into" the sky if haze is present.)

Are there any surface features visible in the telescope? Venus, because of its white clouds, appears to most observers to be featureless — no matter what the phase. However, over the past century or so, observers using medium or large size telescopes have reported dark patchy markings on the clouds. These dark markings are usually described as slightly less brilliant than the dazzling white of the rest of the planet.

We now know that there are many subtle variations in intensity in the clouds of Venus as photographed in ultraviolet light by Earth based telescopes, and by the cameras of Mariner 10 as it swung by the planet in February 1974. But when the ultraviolet photos are compared to drawings of the patchy marks seen by visual observers, the correlation is fair at best. The conclusion of most astronomers is that in general, the patchy Venus markings seen visually through small telescopes are either optical illusions or real phenomena that are so close to the limit of resolution as to be beyond photographic detection in visible light.

OFFSET FROM VENUS TO MERCURY

	R.A. Offset West	Dec. Offset North
May 1	1^h50^m	4.8°
4	1^h42^m	3.1°
7	1^h36^m	2.1°
10	1^h29^m	1.1°
13	1^h31^m	0.9°
16	1^h31^m	0.5°
19	1^h35^m	0.1°
22	1^h40^m	0.1°
25	1^h50^m	0.1°
28	2^h02^m	0.2°

During most of May 1975, Venus will be close enough to Mercury to allow identification of the fainter planet by setting circle offset from Venus.

William K. Hartmann of the Planetary Science Institute in Tucson, Ariz., a professional astronomer and long time planetary observer, believes that one specific patch seen repeatedly for years by many observers is real. It's a zone near the poles sometimes called the *cusp collar.* This dark feature appears on all of the Mariner 10 ultraviolet photos of Venus even though the atmosphere circulates once around the planet at a dizzying 250 m.p.h. (This velocity applies only to the topmost layer of the atmosphere. On the surface, the winds are nearly nonexistent.)

In August, when Venus gets to a phase where we see less than 10 percent of its illuminated face, the cusps (the points at the two ends of the crescent) can sometimes be seen to extend into the nighttime side of the planet. We are actually seeing atmospheric scattering of sunlight. When Venus is a very thin sliver of a crescent, the extended cusps practically ring the entire planet — a rare, delicate and beautiful sight in a moderately sized telescope. Of course, the cusp extensions are due strictly to the atmosphere of Venus. On a world like the moon, we never see anything like it even though we can observe the moon far more clearly than we will ever see Venus from Earth.

One strange feature that has been noted by experienced observers of the nearby planet is the ashen light — an illumination of the nighttime side of Venus visible in Earthbound telescopes. Theoretically, no illumination of the nighttime side of Venus could possibly be visible from Earth. It would have to be of immense proportions to be seen through the brightness of our own atmosphere. However, it has been reported by so many observers that it has become sort of a legend — one that is difficult to dismiss. Hartmann believes that further investigation is necessary to prove that the ashen light does or does not exist. He feels that there are too many recorded observations to write it off as an optical illusion.

The features of Mercury are definitely real variations in the brightness of the planet's surface. They resemble the appearance of the moon to the unaided eye, but are less distinct. However, they are *exceedingly* difficult to observe — requiring a large telescope, good optics, planetary observing experience and excellent atmospheric conditions. Consider it a successful observing session if you find the planet and can clearly distinguish its phase through your telescope.

ASTRO-NEWS

Latest News From the World of Astronomy

Asteroid Occults Star

The first confirmed observation of an asteroid passing directly in front of a bright star has been reported by a small group of professional and amateur astronomers located near Hartford, Conn.

The event, calculated to be a once in a lifetime phenomenon, occurred Jan. 23 during the rare close approach to Earth of the mountain-sized asteroid Eros. The tiny 15 mile wide planet was 14 million miles away — only half the distance of the nearest major planet — when it passed directly in front of the medium bright naked eye star Kappa Geminorum.

"The star completely disappeared for up to three seconds depending on the observer's location along the 10 mile wide occultation zone," said Brian O'Leary, a professor at Hampshire College in Massachusetts who headed up the only successful professional team. Five fortunate amateur astronomers also reported observing the rare incident.

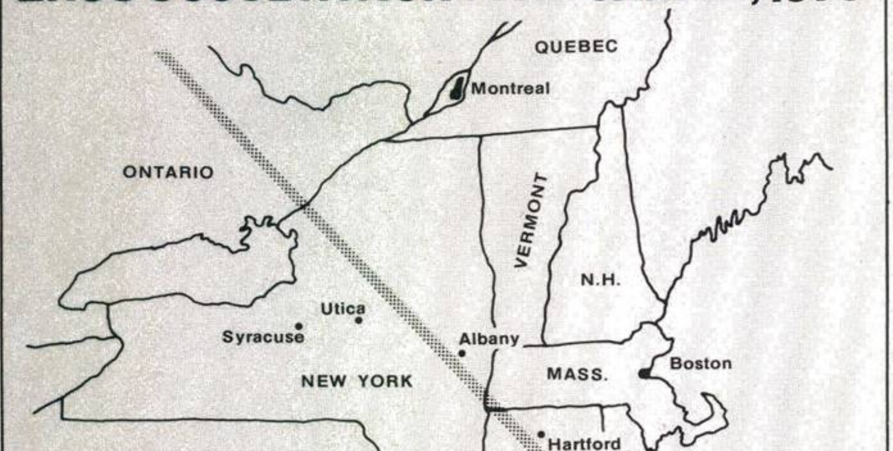
The event — properly called an occultation — was clearly visible to the unaided eye, but minute uncertainties in the calculated orbit of Eros relative to Earth kept astronomers guessing as to just where it could be seen.

The phenomenon was really a tiny eclipse with Eros casting its feeble shadow on Earth. Unlike an eclipse of the sun, the light source was an ordinary distant star.

"We couldn't pin down the exact track of the occultation until four hours before it occurred," reports Brian Marsden of the Smithsonian Astrophysical Observatory. Marsden notified O'Leary who instantly dispatched 18 teams of volunteers (mostly students) to the predicted location in western Connecticut.

The teams, most consisting of an observer and assistant, were to be spread at four mile intervals west from Hartford. The last minute refinements of the predictions partly foiled the project since one of the successful teams had to race to the site by car at 70 m.p.h. The coverage was necessarily less complete than would have been possible with more advance notice.

EROS OCCULTATION PATH JAN. 23,1975.



Yet, it is remarkable that precise accuracy in predicting the path was possible at all. An error of 0.6 seconds of arc in the position of either Eros or the reference stars meant shifting the zone of occultation from one side of Connecticut to the other. Pinning Eros' position down required excellent high resolution photos of Eros and surrounding stars taken as close as possible to the date of occultation.

"Previous calculations revealed the occultation would occur somewhere over New England, but we couldn't refine the data until the last minute," said Marsden.

The rarity of the event — an occultation of a bright star by an asteroid — is enormous. There is no recorded instance of one in the past and none predicted for the future. New refinements in orbital statistics could change that; there are some faint stars due to be winked out in coming years. (None of the predictions for this year are visible from the United States.)

Of what use are these asteroid occultations? The main items of new information that can be gained are precise asteroid diameter measurements. One of the satellites of Jupiter had its diameter refined to the nearest mile by exacting observations made when it passed in front of a star.

Asteroid diameters can give major clues to unraveling the origin of these small planets which normally circle the sun far from Earth, between Mars and Jupiter. Insight into their origin ultimately enhances our knowledge of our own beginnings.

Skylab Rips Hole in Ionosphere

At 12:39 p.m. (EST) on May 14, 1973, radio observatories in Labrador, Massachusetts and Illinois witnessed a 1,200 miles diameter "hole" torn through the ionosphere. Within seconds, 70 percent of the free electrons within this region vanished.

"We could hardly believe the record at first," confessed astrophysicist Gerald Hawkins. With equal disbelief Hawkins, John Klobuchar of Air Force Cambridge Research Laboratories, and Michael Mendillo of Boston University concluded that the bizarre event was caused by the launching of the Skylab space station.

As the liquid hydrogen/liquid oxygen powered second stage of the Saturn 5 booster hurled Skylab into orbit, the engines left behind a rapidly expanding exhaust wake of 70 percent water vapor and 30 percent molecular hydrogen. Flooding into the ionosphere at one ton per second, these new gases immediately upset chemical balances by reacting with oxygen ions to create a surplus of positively charged ions (atoms lacking electrons). These new ions in turn combined with free electrons, emptying a large area of the ionosphere's radio reflecting F-region of its normal electron blanket. Within 1-1/2 hours this gaping wound began returning to normal.

Although environmentalists have warned about the danger of unpredictable effects by rocket exhausts in the upper atmosphere, Hawkins assures that this particular phenomenon "is not a one-way ticket to the destruction of the environment." The sun's energy efficiently repairs a "damaged" ionosphere by constantly providing fresh negative electrons through breaking up or ionizing oxygen atoms. Even if such launches regularly perforated the ionosphere, conditions would quickly return to normal. "You can't compete with the sun," he emphasizes. Hawkins also points out that the chemistry causing the temporary imbalance, water vapor and molecular hydrogen, is so natural to Earth's atmosphere that it can hardly be considered a pollutant.

Mendillo sees the ability of creating such an electron hole as an opportunity for learning more about the effects of Earth's magnetic storms. Normally, solar flare activity depletes 50 percent of the ionosphere's electron content through magnetic storms. These electron losses can interfere with ground based and satellite radio communication. Through small man made storms, scientists could better understand the physics behind electron disruptions. Mendillo suggests that such a controlled experiment in space could be performed by having the Space Shuttle (planned for flights in the 1980s) release hydrogen or oxygen into the ionosphere

Earlier Saturn 5 launchings did not poke any ionosphere holes because their second stage engines burned out below 110 miles, the altitude where such chemical reactions occur. To kick Skylab into orbit, a longer and higher second stage burn was required.

Soyuz Landing Paves Way for Joint Mission

The two-man Soyuz spacecraft safely returned to Earth on Feb. 9, 1975, successfully completing the last Soviet space mission before the upcoming July Apollo/Soyuz space rendezvous. Cosmonauts Alexei Gubarev and Georgi Grechko spent all but one day of their 30 day Soviet record-breaking mission (the United States record is 84 days) within the five ton Salyut 4 space station. The crew appeared healthy after the long flight although they experienced several days of fatigue responding to the renewed effect of gravity.

Although Soviet officials deny that the flight was related to the Apollo/Soyuz rendezvous, Western experts consider Soyuz 17's success as evidence that the USSR is technologically ready for the international space mission. Earlier Soviet space setbacks caused some concern for American officials as to the safety of a joint mission. In 1971 a faulty airlock depressurized the cabin of Soyuz 11, instantly killing three cosmonauts. Only last August, repeated docking failures between the Soyuz 15 and Salyut 3 abruptly scrubbed that mission.

On July 18, 1975 the Apollo and Soyuz spacecraft are scheduled to rendezvous and link-up in Earth orbit. A special docking module will allow U.S. and Soviet crews to transfer between vehicles. After two days of joint science experiments, the two spacecraft will undock and independently return to Earth.

Water Discovered in Jovian Atmosphere

Water, one of the most important constituents of Earth life, exists in the atmosphere of Jupiter according to University of Arizona scientists. This is the first time an oxygen-bearing molecule has been identified in one of the solar system's gas giant planets.

An infrared spectrometer flown eight miles above Earth's obscuring atmosphere made the historic discovery. The observations show that water lies deep within the Jovian atmosphere, at a region where air pressure is 20 times greater than Earth's.

There is strong evidence that Jupiter is a bloated ball of liquid and metallic hydrogen, lacking any discreet "surface" that life could evolve on (although a rocky core probably lies at the planet's center). But within the giant's 600 mile deep atmosphere there is likely a zone where pressures, temperatures and chemistry favor the evolution of life.

Recent models of the Jovian atmosphere predicted that water droplets should be found at depths where temperatures are Earthlike. Now, confirmation of water's presence adds new evidence for life on the huge planet.

Ammonia, methane and hydrogen — chemicals also considered important precursors to life — exist abundantly on Jupiter. Laboratory experiments demonstrate that electrically sparked mixtures of these elements and water create amino acids, the fundamental building blocks of Earth life. Titanic lightning explosions in Jupiter's atmosphere may, on a grand scale, be manufacturing similar chemicals. The organic molecules ethane and acetylene have already been identified as part of Jovian chemistry.

Whether life forms could evolve and survive being forever suspended in Jupiter's turbulent atmosphere remains a tantalizing mystery. The answer will probably have to wait until unmanned probes someday plunge into the solar system's largest planet.

Sodium Found in Atmosphere of Jovian Moon

Before pioneer 10's mission to Jupiter and beyond, the only satellite in the solar system known to have an atmosphere was Saturn's giant moon Titan. Astronomers had sometimes speculated that one or two of the other large satellites — such as Ganymede or Triton — might also possess an atmosphere of sorts, but all the others were dismissed as impossible.

The discovery by Pioneer 10 that Io has a thin atmosphere was a real surprise. Any atmosphere around Io, the innermost Galilean satellite of Jupiter, would have been expected to bleed off in a matter of months — or a few years at most — for two reasons. First, Io's gravity is too feeble to hold on to an atmosphere. Second, Jupiter is too close — the point of null gravity on the Jupiter-Io line is less than 500 miles above Io's surface. (In contrast, the point of null gravity on the Earth-moon line is more than 20,000 miles above the lunar surface, even though the moon is about the same size as Io and roughly the same distance from its primary.) So something must be constantly replenishing Io's atmosphere.

The fact that Io's atmosphere (corresponding in density to the atmosphere about 150 miles above Earth's surface) is primarily hydrogen (lightest of all gases and therefore the one that could escape most easily) was a further surprise. Sodium was also detected, and later ground-based observations confirmed that the sodium spectrum of Io is a bright-line spectrum. In order to produce bright lines, the sodium must be at a considerably higher temperature than its surroundings. What is heating it up?

These puzzles were added to the long list of unanswered questions about Io, perhaps the most enigmatic moon in the solar system. For instance, why are the radio signals from Jupiter so much stronger when Io is on its near side? Why does Io have such a high albedo reflecting more than 60 percent of the light it receives from the sun?

All these conundrums have sparked an intense interest in Io, and aided by recent ground-based observations, scientists have now been able to construct a model of Io that explains most of the puzzles.

sodium *continued on page 64*

Observations Support Black Hole Theory

Black holes — incredibly dense, collapsed stars having tremendously strong gravitational fields — have yet to be positively identified in space. An increasingly popular black hole candidate, however, is the second brightest X-ray source in the sky, Cygnus X-1. Caltech physicist Kip Thorne and University of Utah physicist Richard Price report that a recent comparison between Cygnus X-1 observations and theoretical models of black holes support the belief that the X-ray source is indeed the location of a black hole.

About 7,500 light-years from Earth, Cygnus X-1 consists of a blue supergiant star and an unseen X-ray source roughly 10 million miles away. Spectroscopic observations show that glowing gas is continually being pulled off the visible star and toward the unseen companion. If Cygnus X-1 is a black hole, theory says that it should be surrounded by a flat, whirling disc of very hot gas feeding into the hole's intense gravity. Astronomers infer the existence of just such a disc around Cygnus X-1 from studying the fluctuating intensity of its X-rays at various wavelengths. X-rays would be generated from the multimillion degree temperature of the gas.

A recent British-Russian theory — modified by Thorne and Price to conform to Einstein's theory of general relativity — suggests that the accretion disc has two discreet regions where X-rays are emitted. Interpretation of the observations confirms that Cygnus X-1 has an outer area 600 miles wide and a few miles thick surrounding an inner region 60 miles wide and about 10 miles thick.

While the outer zone is opaque to X-rays, the inner disc is translucent to X-rays. This means the inner region is much hotter, emitting higher energy X-rays than the outer one, and that there are two distinct frequencies of X-rays — a higher energy inner region of 15 to 20 thousand electron volts and a lower energy outer region of one to three thousand electron volts. These findings indicate the theory is on the right track.

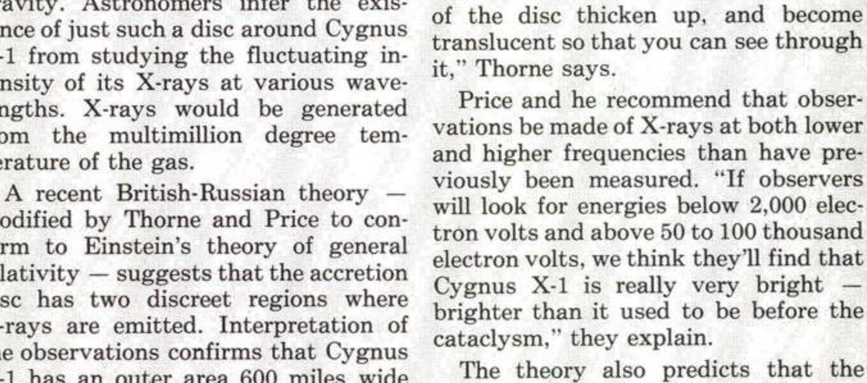
In March 1971, Cygnus X-1 suffered a cataclysm of some kind. The pattern of X-ray emissions changed drastically; the intensity of low energy X-rays diminished considerably. According to theory, the thick inner region of the disc probably expanded from 60 to 120 miles in width, "eating up" some of the thinner, outer region. In these instabilities the gas ceases to be a smooth disc and breaks into a series of high density rings with near vacuum in between them. The rings then fragment into narrower rings, with higher vacuum in between. Eventually the rings can't support themselves against the energy that's being generated in them and they explode like a bomb.

"That makes the innermost 120 miles of the disc thicken up, and become translucent so that you can see through it," Thorne says.

Price and he recommend that observations be made of X-rays at both lower and higher frequencies than have previously been measured. "If observers will look for energies below 2,000 electron volts and above 50 to 100 thousand electron volts, we think they'll find that Cygnus X-1 is really very bright — brighter than it used to be before the cataclysm," they explain.

The theory also predicts that the high energy X-rays should fluctuate more than the low. Recent observations are showing this probably to be true.

Thorne is about 80 percent convinced that Cygnus X-1 contains a black hole. "Future confrontations between observations and theory may strengthen that conviction — or may destroy it," he says.



"MAYBE IT'S AN INTERSTELLAR DIRTY JOKE CHAIN LETTER?"

Astronomers Hotly Debate True Destiny of Universe

Will the universe exist forever or will it someday collapse back upon itself like a deflating balloon, ending in a fireball instantly obliterating all that exists?

Astronomers from around the world recently met in Dallas, Tex. to unravel this profoundly fundamental question. Some of their latest observations predict an eternal but lonely existence for the universe, although its true destiny remains one of modern science's hottest debates.

Through most of history, man has thought of the cosmos as a stable, tranquil and eternal entity. Only during the past 60 years have observations uncovered an incredibly dynamic universe that seems to literally be coming apart at the seams. The fundamental discovery, made 50 years ago, concerns the recession of the galaxies. Much as the siren of a receding ambulance is stretched into a lower pitch, light from other galaxies is stretched into a lower frequency or color. This so-called redshift indicates that galaxies and clusters of galaxies are all flying away from us — some at incredible speeds.

The universe's odd behavior, reminiscent of a bursting 4th of July skyrocket, implies that things got started in a fantastic explosion billions of years ago. Galaxies might be thought of as cooling, condensing embers flung outward from this "big bang".

The key question to unlocking the future of the universe simply asks if clusters of galaxies are flying apart fast enough to escape the braking effect of their mutual gravitational pull on each other. Although astronomers at the Dallas conference attacked this puzzle in many different ways, they basically wanted to know two things: How quickly is the universe slowing down from its expansion? Is there enough mass in space to gravitationally pull the galaxies back together?

If the expansion rate has remained fairly constant since the big bang, then gravity has had a negligible effect on retarding the runaway galaxies, making the universe "open". If instead clusters of galaxies are flying apart appreciably slower than billions of years earlier, this deceleration will continue until expansion eventually halts, meaning that the universe is "closed". For an instant all galaxies will hang motionless in space and then begin falling back toward each other as inevitably as a rocket crashes back to Earth if it fails to reach escape velocity.

Unfortunately astronomers can't magically summon up an instant replay of the galaxies' deceleration rate over the past 12 or so billion years. But they can glimpse into the past by observing quasars, the most distant known objects. Their light began its Earthward journey billions of years ago. (In fact, the discovery of quasars in the early 1960s first prompted this series of seven conferences on cosmology.)

But quasars are so bizzare that they have only sparked further debate. If these starlike objects are at the multibillion light-year distances their redshift indicates, then their outpouring of light and radio energy seems too powerful to be generated by an energy source we can imagine. This leads some astrophysicists to challenge the use of quasar data even if the redshift yardstick for measuring speeds and extreme distance is reliable.

Another trick for turning the cosmological clock backwards involves comparing the universe's age with how old it would be now if the present rate of expansion remained nearly always the same. If gravity has hardly slowed down the inflation, both ages should be identical. But if the cosmos is significantly slowing down, what we believe is the real age should be shorter than the calculated constant expansion age.

This would, for example, be similar to determining if a car is decelerating by comparing its actual travel time to the travel time inferred from its present speed. We'll start out only knowing that the auto has covered 300 miles. As it passes by we measure its present velocity at 50 m.p.h. If the car has not been moving any faster earlier in its trip the travel time should be no shorter than six hours (300 miles divided by 50 m.p.h.). But a dashboard stopwatch reads only four hours actual travel time. This two hour discrepancy means that the car must be decelerating from a faster velocity.

Astrophysicists approximate the universe's age by measuring the radioactive decay of elements, believed to be first formed two billion years after the primordial big bang. They learn the universe's present expansion rate by plotting the galaxies' brightnesses against their velocity, or redshift. This value is being constantly recalculated and refined.

Allen Sandage of Hale Observatories recently calculated this expansion rate as 34 miles per second per 3.26 million light-years — meaning that for every increase of 3.26 million light-years from us, matter is moving away 118,300 m.p.h. faster. Sandage determined that the universe's age (inferred from assuming this speed is constant just as with our 50 m.p.h. car) closely agrees with the age of the elements — about 10 to 14 billion years. From these results he argued in Dallas that the universe is not decelerating fast enough to prevent it from expanding forever. But other astrophysicists complained that the margin for the age of the elements is much wider (8 to 15 billion years) — too broad for an accurate idea of the universe's birthdate.

Another vote for an open universe came from University of Texas astronomer Beatrice Tinsley. From studying the life history of stars within a galaxy she concludes that distant galaxies were brighter when their light long ago started for Earth. This would fool astronomers into thinking that clusters of galaxies are closer than they really are, since astronomers usually assume that a galaxy's light output remains constant. Her corrections to deceleration estimates mean an open universe by an "embarrassingly large margin", she said.

The other main road of attack involves estimating the total mass of the universe. In one approach astronomers divide the sky into narrow segments, carefully count up the number of galaxies in a representative number of segments, and estimate the mass of each segment. Multiply that number by the number of segments and you have the so-called *luminous mass* of the universe.

The other way is to select a cluster of galaxies, establish the speed and direction in which each member galaxy is moving with respect to the center of the cluster, and from that determine what the mass of the cluster must be. This is the so-called *virial theorem* method.

The trouble is that the results from these two methods don't agree. The luminous mass averages out to an overall density of only about one hydrogen atom every five or six cubic yards. The virial theorem, on the other hand, gives values that are typically from 10 to 100 times the luminous mass — enough to eventually pull the galaxies back together.

The only way to reconcile the two results is to assume that from 90 to 99 percent of the mass of the universe is locked up in nonluminous material — the so-called *missing mass*. Possibilities are black holes, "dead" galaxies that no longer radiate, dwarf galaxies that are intrinsically too faint to be seen at large distances, or intergalactic matter.

Black holes are an unknown quantity. Some theorists speculate that black holes could constitute more than 90 percent of the mass of the universe — but so far there is no observational evidence to support this theory. Likewise, dead galaxies have never been observed, and there is no compelling reason to suppose that they ever will be. Dwarf galaxies certainly are observed — in fact, they are probably the most common type of galaxy in the universe. At least 15 of the 20 galaxies in the Local Group are dwarfs, but all 15 together have less mass than our own Milky Way galaxy. It's unlikely that dwarf galaxies could account for much of the missing mass of the universe.

Many astronomers have felt that intergalactic matter is the best bet for supplying the missing mass. It has long been suspected that the vast reaches of space between galaxies are not a perfect vacuum. Exploding galaxies are known, and the material they eject must go somewhere. But until now all efforts to detect intergalactic matter have failed. The temperature of the intergalactic medium is very close to absolute zero, and it would presumably be very hard for an atom there to acquire enough energy to radiate and thus make its presence known to us.

But now the picture has changed. Three Australian astronomers have furnished the first real evidence that intergalactic matter exists; they used the 55 foot radio telescope at Parkes Observatory in New South Wales to observe the Sculptor group of galaxies. (The Sculptor group is a small cluster of five galaxies about 10 million light-years distant, lying near the south galactic pole.) They found that at least two of the Sculptor galaxies are surrounded by vast clouds of hydrogen gas more than a half million light-years long. The overall density in these clouds is about 800 atoms per cubic yard.

Others suggest that large invisible concentrations of intergalactic material might be detected through their gravitational distortion on neighboring galaxies. Gerard de Vaucouleurs of the University of Texas believes that his discovery of unusually high expansion velocities within the supercluster of galaxies that our Milky Way inhabits might be evidence for hidden matter. Jeremiah Ostriker of Princeton also claims that galaxies are surrounded by huge spherical regions of material. Almost 20 times the volume of the galaxies themselves, the "halos" would increase the mass of a cluster of galaxies tenfold.

But so far no one has convincingly found enough missing mass to give our universe enough gravitational glue. At the conference some cosmologists doubted that they ever would. For example, Caltech astronomer James Gunn argued that the cosmos falls 10 to 20 times short of the required mass.

In another approach to determining total mass, astrophysicists have devised a recipe for what should have chemically "cooked" in the first chaotic seconds of the big bang. Within the initial fireball's three billion degree oven, hydrogen — the only element then in existence — fused with free floating neutrons to form deuterium (heavy hydrogen). If the newborn universe was massive enough to be closed, most deuterium should have continued fusing with protons and neutrons to create helium. Since astrophysicists don't know of any process that would still be making deuterium today, its abundance in space seem an accurate reflection of the universe's mass. In Dallas, Gunn emphasized that the ratio of deuterium and helium suggests that the universe is open, because a lot of deuterium is still present in space. But just as with other approaches, these findings are still being debated.

Many astronomers find the concept of a closed universe more attractive — some on philosophical or even "religious" grounds. A closed universe lasts a definite length of time and occupies a finite amount of space. It offers the tantalizing prospect of a sort of cosmic reincarnation, where a collapsing universe dies in an explosion that in turn marks the birth of a new universe. Some cosmologists envision an endless chain of expansion and contraction cycles — the so-called *oscillating universe* theory. This concept cleverly sidesteps the uneasy question of what preceded the birth of our universe.

Proponents of an open universe must face some very uncomfortable concepts. The open universe is eternal and fills an infinite amount of space. It also implies that an infinitely powerful blast was needed to distribute the mass.

We may have to wait for the large-scale radio antenna arrays and orbital telescopes of the future before resolving this timeless riddle. All we can be fairly sure of now is that a humbling destiny awaits our universe. Either the glittering clusters of galaxies will all disintegrate like melting snowflakes, or fade into infinity like a wisp of smoke.

Hale Observatories Photograph

Galaxies seem to travel in groups as evident in this Palomar Observatory photograph of the central portion of a cluster of galaxies in the constellation Corona Borealis. Seven hundred million light-years distant, this spectacular collection of more than 400 galaxies represents one of the more remote clusters known. It is speeding away from us at 13,000 miles per second (about 1/14 the velocity of light). All other galactic clusters are also receding from Earth at varying speeds, suggesting that the entire universe is expanding. The article on this page describes recent attempts to settle the question of the nature and ultimate result of the expansion.

Palomar Seeing Rated Excellent

The environment for observing at the world's largest, most productive telescope — the 200 inch at Palomar Observatory in California — remains nearly as good as it was 40 years ago when the site was selected, according to director Horace Babcock of the Hale Observatories.

Babcock commended the United States Forest Service, San Diego County and neighboring ranchers for helping to preserve the excellent seeing conditions which are free of dust, smoke, heavy traffic and significant artificial light. The observatory is located atop Palomar Mountain, 135 miles from Los Angeles and 70 from San Diego.

"It's a tribute to the observatory's neighbors that artificial lights on the mountain have been held to an absolute minimum," said Babcock. "Palomar Mountain, within a radius of several miles of the observatory, continues to consist almost entirely of unspoiled forest areas interspersed with grass covered valleys."

Night sky glare reaching the Palomar site from artificial lights in the populated valleys and coastal plains has worsened somewhat over the years. Astronomers at Palomar have lost at least 0.1 magnitude due to artificial sky glare — and although not serious, it can be compared to the situation at Lick Observatory near San Jose where 1.0 to 1.5 magnitudes have been whipped off the theoretical lower limit of the 120 inch telescope by persistent urban growth.

Among other threats to the observatory's environment that have been minimized through the cooperation of government agencies is that of low flying aircraft. In 1971 flight paths for low flying military jets were established over Palomar Mountain, with two flight paths intersecting over the dome of the 200 inch telescope. Observatory officials discussed the matter with the Federal Aviation Administration (FAA) and as a result the flight paths were relocated.

The FAA also has been considerate in avoiding installation of microwave beams or radar equipment in the observatory's vicinity that would disturb sensitive electronic observations, Babcock added. However, one aircraft problem remains. High flying planes within a few miles of the observatory leave streaks on photographs made by the telescopes at Palomar and also leave persistent trails of air turbulence that disturb astronomical observations by distorting the line of sight. The FAA is cooperating with the observatory in studying the matter.

Superb seeing conditions are vital in enabling the great 200 inch telescope to make maximum use of its light-gathering power — the equivalent of a million human eyes — which is greater than that of any other operating telescope. This power is essential for the observation of galaxies and quasars at the far reaches of the universe. The telescope's observing time is booked up more than a year in advance by staff and visiting astronomers.

Conceived by George Ellery Hale, founder of Mt. Wilson and Palomar Observatories, and built in the 1930s and 1940s at a cost of about $7 million, the big telescope is expected to have a useful lifetime of at least 100 years. Its replacement cost today would be about $30 million, Babcock estimated.

Space Research Lab Planned for 1980s

NASA has recently begun developing the first in a series of manned scientific payloads to be orbited by the Space Shuttle in the 1980s. The project marks the first step toward resumption of scientific space exploration by manned spacecraft after this year's joint Apollo-Soyuz mission.

Named AMPS (Atmospheric Magnetospheric and Plasmas-in-Space payload), the laboratory will carry a variety of instruments for probing Earth's atmosphere and magnetic field — including an electron accelerator and high powered transmitters. Remote controlled devices mounted outside the lab will utilize the vacuum and zero gravity of space for conducting plasma physics experiments.

For the first time scientists from government, education and industry will be able to conduct research within the space environment. The crew of four experts selected for each flight can have their own special experiments carried aboard the laboratory.

AMPS will be installed inside a space "box car" called Spacelab, currently under development by he European Space Research Organization (ESRO). Within Spacelab, scientists will live and work in a shirtsleeve environment for up to two weeks in orbit.

The cylindrical shaped module will be carried into space by the Space Shuttle. Scheduled for completion around 1980, the Shuttle represents America's first reusable space transport system. Once in orbit, the Shuttle's cargo bay doors would open up, exposing the laboratory to outer space. Throughout the mission Spacelab will stay coupled to the Shuttle in a piggyback fashion. From an orbit of a few hundred miles the AMPS payload will enable study of such down-to-Earth problems as communications blackouts, atmospheric pollution, and relationships between the sun's energy and Earth's weather patterns.

The NASA Marshall Space Flight Center in Huntsville, Ala. is working in cooperation with an international team of 49 scientists in designing the AMPS laboratory.

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sodium *continued from page 61*

Io is believed to be covered with salt, either alone or dissolved in frozen ammonia. It is known from Pioneer 10 that the long loop of Jupiter's outer radiation belt crosses Io's orbit. As Io passes through the loop, charged particles trapped in the Jovian magnetic field strike the salt covered surface of Io, ionize the salt or ammonia they strike, and eject it into the atmosphere. As the particles in the atmosphere orbit Io, they approach the sub-Jupiter point, where the strong Jovian gravity tears them away into an orbit around Jupiter. On subsequent passes, Io recaptures some of them — only to lose them again at another point in its orbit. (There must be magnificent auroras in Io's sky!) This continual tug of war heats the cloud to thousands of degrees, and generates an electric current that accounts for the enhancement of Jupiter's radio signals.

Scientists are now hard at work reducing the data from Pioneer 11 which they hope will give them a still clearer picture of Io.

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STAR DOME

April

As evenings grow shorter, the winter family of constellations continues to retreat from April skies as if out of fear that their bright stars will somehow melt during the warm nights. Only a few months ago Orion the hunter was dominantly striding overhead. Now he appears humbly suspended above the western horizon — his back turned to the encroaching spring menagerie.

Although we'll miss winter's splendid star show, spring has its own unique set of wonders if you know where to look. We need the equivalent of an old-fashioned country guidepost to lead us around the dim spring constellations. The Big Dipper, most popular of all star patterns, makes a reliable direction marker. The Big Dipper is a member of the *circumpolar* constellations — those figures that are always visible above the northern horizon (from our latitude) no matter what season or time of night.

Seven stars of almost equal brightness trace the dipper's cup and handle. In spring the dipper might be slightly harder to visualize since it appears to hang upside down, dumping water on the northern horizon. Every Boy Scout knows that by extending a line from the two "pointer stars" opposite the Dipper's handle you will find Polaris, the North Star. As the closest star to the celestial pivot point for Earth's axis, Polaris seems to magically sit almost stationary as all other stars obediently trace circles and arcs across the night sky. Polaris marks the tip of the handle of the "Little Dipper" — a faint version of the Big Dipper, only 2/3 the size.

Finding Polaris requires starting a line from Merak, the pointer star in the *bottom* of the cup, and moving up toward Dubhe, the star on the cup's rim. If you get the procedure backwards the line will carry you headlong into the jaws of Leo the lion, one of the better known members of the spring constellations.

Unlike most constellations, Leo resembles his namesake. A row of stars shaped like a sickle or backwards question mark identifies his head and mane. A distinct right triangle of second and third magnitude stars represents his hindquarters.

At the base of the sickle in Leo gleams blue-white Regulus, one of the few gems in the spring skies. Regulus lies almost exactly on the roadway of the sun and planets — the ecliptic. But at a distance of 84 light-years, this neighbor presents no traffic hazard.

Although Regulus is the faintest of all first magnitude stars (at magnitude +1.3), its association with Leo has, through antiquity, cast it as the ruler of the stars. This star was originally labeled "Rex the king". Nicholas Copernicus renamed it Regulus after the famous consul of the 1st Punic War. With Sirius in Canis Major (the big dog), Regulus shares the reputation of causing hot, "dog days". Ancients believed that the energy of Sirius and Regulus combined with the sun to make summer a hot time of year.

One other noteworthy star in Leo is Denebola, the brightest star in the lion's triangle at magnitude +2.2. An extremely hot star like Regulus, Denebola lies 39 light-years away.

Following a line drawn from Denebola to Alkaid (the star at the end of the big dipper's handle) brings us to Coma Berenices. This extremely faint constellation is really a dispersed star cluster. Consisting of fifth and sixth magnitude stars, it is a real challenge for sky observers. Even the most skilled stargazers confess to detecting it by naked eye only on rare accasions. A perfectly clear moonless night in the deep country is a prime requirement for catching a glimpse of this sprinkling of stars. Through low power binoculars or opera glasses, about 30 shimmering stars fall into focus.

Coma Berenices means the "hair of Berenice". Legends describe Berenice as an ancient Egyptian queen. When her husband King Euergetes set out

The Whirlpool galaxy — also known as M-51 — is one of the nearest and brightest spiral galaxies. With an overall magnitude of eight, this system of stars is a fascinating object for both observers and astrophotographers. A cold emulsion camera attached to a 16 inch Newtonian reflector was used for this High Speed Ektachrome photo.

Photograph by Orien Ernest

for battle with the Assyrians in 250 B.C., Berenice promised her long golden hair to the gods if the king safely returned. When he victoriously came home two years later, the queen — true to her oath — cut off her locks and placed them on the altar in the temple of Venus.

The following morning her hair disappeared. Perhaps unjustly, the theft brought down the king's anger on the poor royal astronomer. To save his neck the clever astronomer explained that Venus was so impressed by Berenice's offering that the goddess placed the golden hair in the heavens as an eternal symbol of the queen's love. That night he pointed out the glittering star cluster as evidence of Venus' miracle. The astronomer was lucky that it wasn't a hazy night! He was even more lucky that the royal couple hadn't previously done much stargazing, as they were easily convinced that Coma Berenices was a new sky addition.

Near the star cluster lies the galaxy's equivalent of Earth's northern sky pole (near Polaris). If you dropped an axis perpendicular to our disc shaped Milky Way galaxy — like placing an axle through a bicycle wheel — one end would aim in the direction of Coma Berenices. We call this invisible point the north galactic pole.

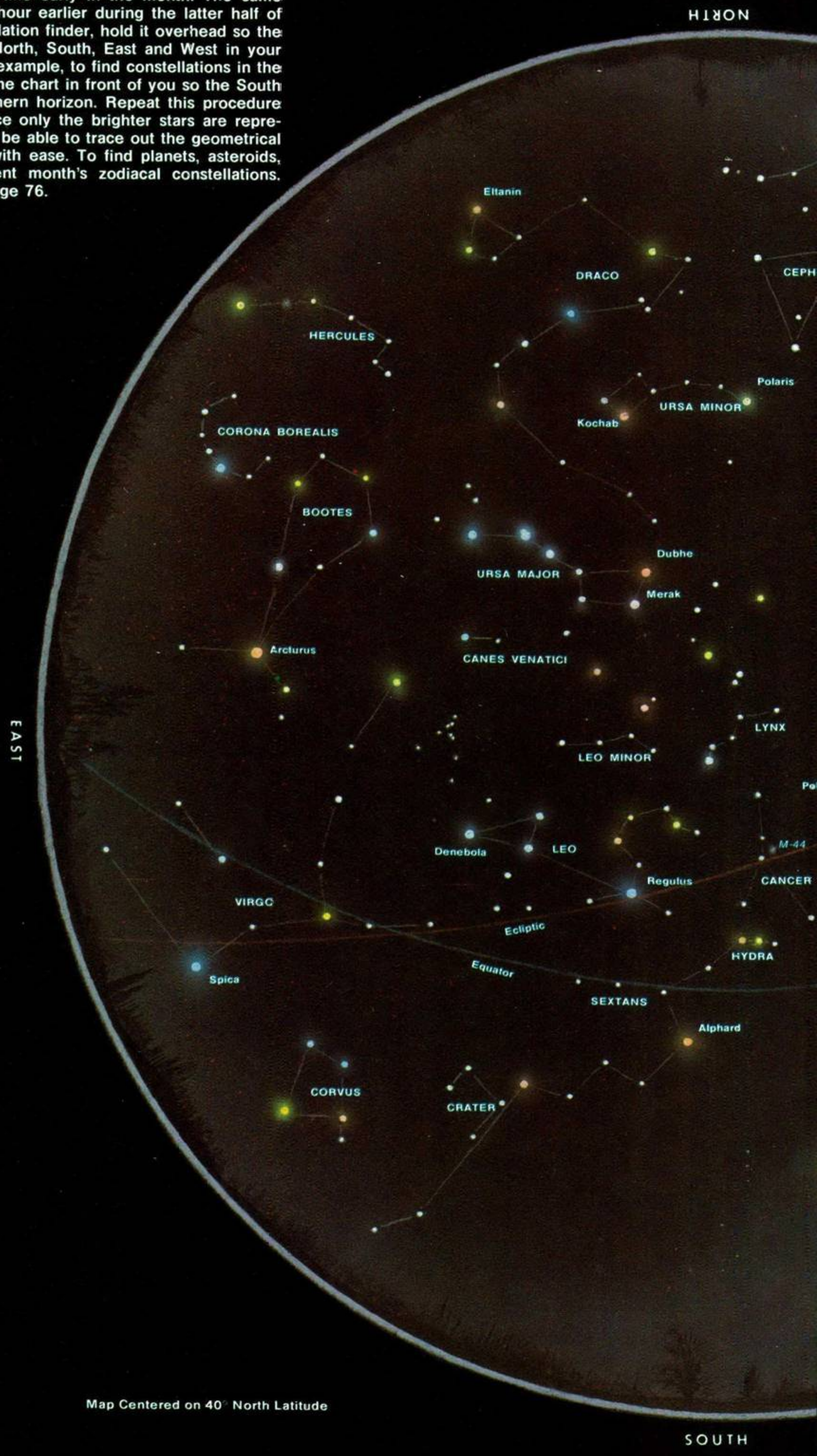
Our imaginary line next enters Canes Venatici (KAY-neez ven-AT-iss-si), the hunting dogs. Named Asterion and Chara, the dogs are relative newcomers to the spring sky. In 1690 astronomer Johan Hevelius squeezed them into a star chart he published. Their latecoming is no surprise since only an N-shaped pattern of five inconspicuous stars accounts for the two dogs. The only modestly bright star present is Cor Caroli (kor KAY-roe-lye) meaning "Charles' heart". Sir Edmund Halley named the star in honor of the coronation of England's King Charles II.

Bootes (Bow-OH-teez), the bear driver, follows Asterion and Chara across the sky. The Big Dipper's handle points in a curving arc toward Bootes, and five relatively bright stars outline a kite shaped pattern identifying him. At the kite's bottom, reddish Arcturus blazes at magnitude +0.2. A cluster of fourth magnitude stars near the end of the Dipper's handle symbolize Bootes' upraised hand grasping a leash connected to the hunting dogs.

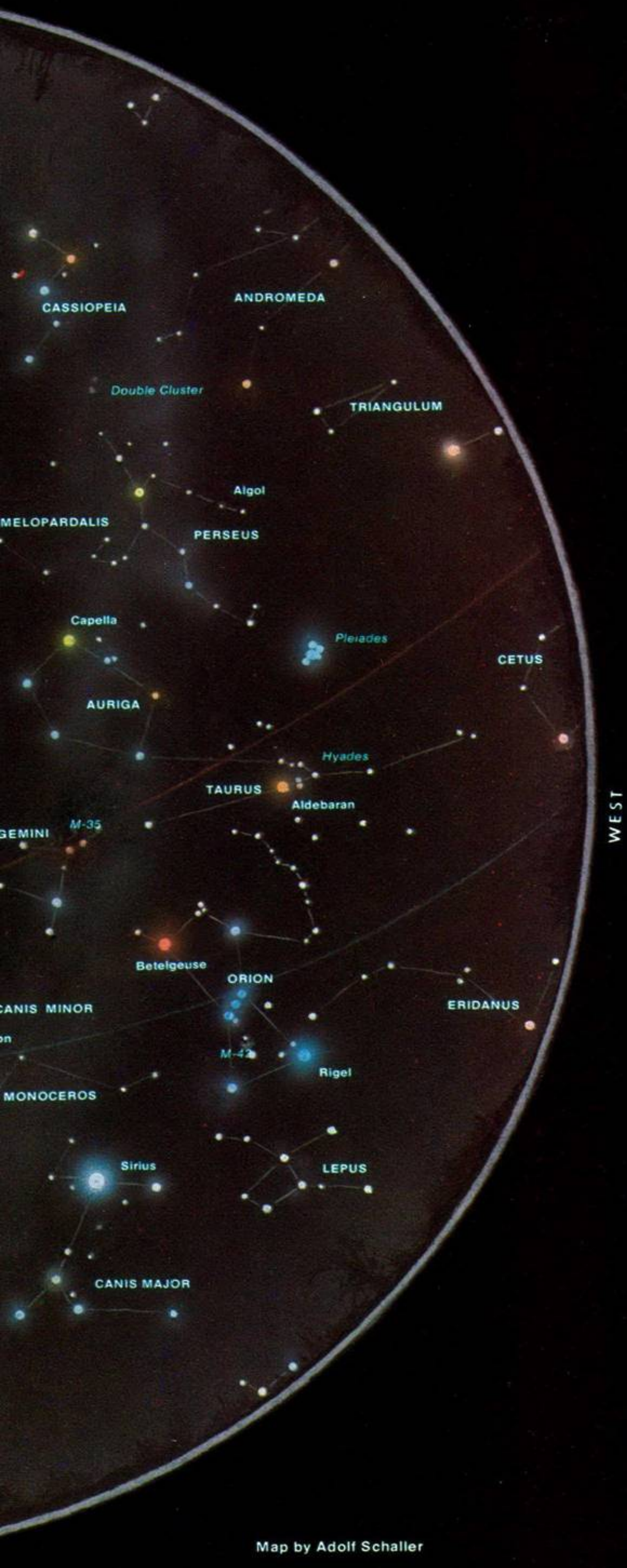
The bear that Bootes is following is represented in part by the Big Dipper. People often mistake the Dipper as being a constellation in itself, when it really is just a star pattern. Although constellations can also be called star patterns, it doesn't work the other way around. For example, we speak of a "summer triangle" star pattern — which actually is made by combining bright stars of three constellations. In the Dipper's case it's only the backside of Ursa Major, the great bear.

Mysteriously, many different cultures told stories of a bear inhabiting this region of the sky

This Star Dome rendering approximates the sky as it appears at about 9 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 76.


NORTH
Eltanin
DRACO
CEPH
HERCULES
Polaris
URSA MINOR
Kochab
CORONA BOREALIS
BOOTES
Dubhe
URSA MAJOR
Merak
Arcturus
CANES VENATICI
EAST
LYNX
LEO MINOR
M-44
Denebola
LEO
Regulus
CANCER
VIRGO
Ecliptic
HYDRA
Equator
Spica
SEXTANS
Alphard
CORVUS
CRATER
SOUTH

Map Centered on 40° North Latitude



Map by Adolf Schaller

even though the star tracing hardly resembles the animal. Contrasted to the Dipper's collection of mostly second magnitude stars, the constellation's remaining stars are quite dim. A large upside down "Y" of stars below the Dipper's cup suggests two hind legs. By stretching your imagination, an inconspicuous "L" pattern in front of the Dipper locates a front leg. A line extended from the two stars on the cup's rim points to a third magnitude star marking the bear's nose.

Mythology explains that the bear was once the maiden Callisto, one of the god Zeus' mortal lovers. Zeus' jealous wife Hera punished the girl by transforming her into a bear shortly after her son by Zeus was born. For years the bear roamed the forests as her son, Arcas, grew into a young hunter. One day the vindictive Hera placed the bear before Arcas, hoping that he would unknowingly kill his mother.

But Zeus intervened just in time. He grasped the bear by its short, stubby tail and flung the creature skyward. This force stretched the tail, as outlined by the stars in the Dipper's handle. After also being transformed into a bear, Arcas was placed alongside his mother in the heavens. Appropriately, the Little Dipper makes up most of the constellation Ursa Minor.

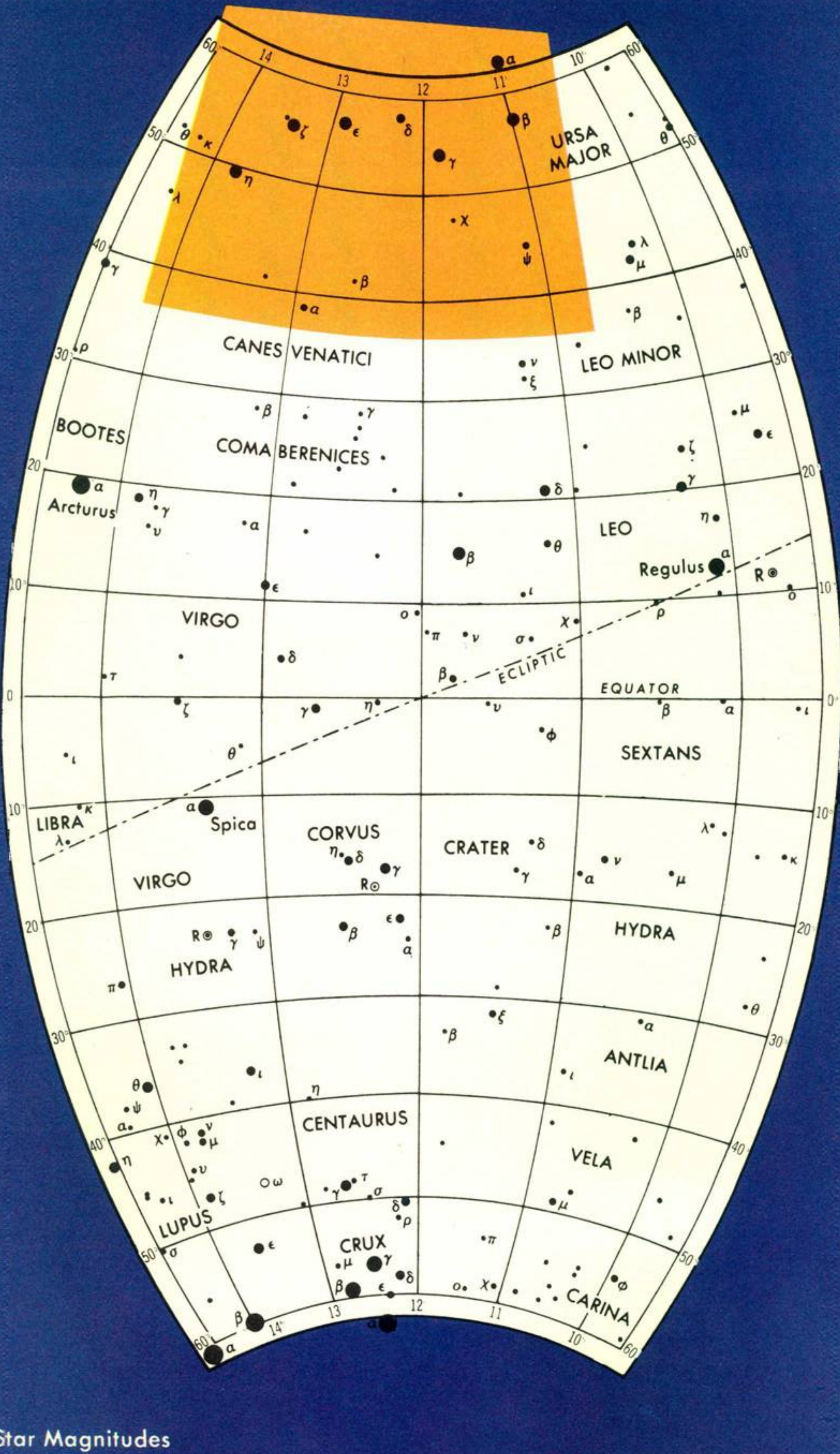
Hera raged with anger. Now as a glittering constellation, Callisto was eternally more beautiful than the goddess. Hera persuaded Neptune, god of the sea, to forbid the bears from bathing in the ocean — as most other constellations do by sinking into the western horizon. To the early Greeks, this explained why — from northern latitudes — the bears never rose or set with the other stars.

North American Indians also imagined a bear in the sky, but their creature was only made up of the four stars in the Dipper's cup. The three handle stars symbolized Indians forever chasing the bear around the sky. The second star from the handle's tip, Mizar, was thought of as an Indian carrying a frying pan to cook the beast in. The pan was represented by Mizar's companion star Alcor.

The legend says that by autumn the hunters came close enough to wound the animal. The bear's blood dripped onto the forests, explaining the brilliant fall colors. Next, the Indian god abruptly called a truce, and both bear and warriors sat down to catch their breath all winter. But now as spring approaches the recovered bear will sprint off again on another chase around the star dome.

Close-Up on the Big Dipper/Canes Venatici Region

The fact that the stars of the Big Dipper are all about the same brightness suggests that the group may be more than simply a random alignment


URSA MAJOR
CANES VENATICI
LEO MINOR
BOOTES
COMA BERENICES
Arcturus
LEO
Regulus
VIRGO
ECLIPTIC
EQUATOR
SEXTANS
LIBRA
Spica
CORVUS
CRATER
VIRGO
HYDRA
HYDRA
ANTLIA
CENTAURUS
VELA
LUPUS
CRUX
CARINA
14
13
12
11
10
60
50
40
30
20
10
0

Star Magnitudes

●	●	●	●	●	●	●	●	●	●
—1	0	1	1½	2	2½	3	3½	4	5

○ Cluster or Nebula

◉ Variable Star

Map from **Guideposts to the Stars**; reprinted permission of MacMillan Publishing Co., ©1972 by Leslie C. Peltier.

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α	**Alpha**	η	**Eta**	ν	**Nu**	τ	**Tau**
β	**Beta**	θ	**Theta**	ξ	**Xi**	υ	**Upsilon**
γ	**Gamma**	ι	**Iota**	ο	**Omicron**	φ	**Phi**
δ	**Delta**	κ	**Kappa**	π	**Pi**	χ	**Chi**
ϵ	**Epsilon**	λ	**Lambda**	ρ	**Rho**	ψ	**Psi**
ζ	**Zeta**	μ	**Mu**	σ	**Sigma**	ω	**Omega**

of stars. Let's take a look at these seven stars to see if they are in fact related. Here is a table listing some statistics:

Name	Magnitude	Distance (light-years)	Spectral Class
Dubhe	1.8	105	K0
Merak	2.4	78	A1
Phecda	2.4	90	A0
Megrez	3.3	63	A3
Alioth	1.8	68	A0
Mizar	2.2	88	A2
Alkaid	1.9	210	B3

The most striking similarity is the grouping of five of the seven stars in spectral class A. All five are within the narrow range from class A0 to A3 — indicating they are somewhat hotter and larger than the sun. Similar spectral characteristics is a strong sign of physical relationship. But we also note that these same five stars are between 63 and 90 light-years away.

With both distance and spectral similarities, there seems no doubt that the five stars — Merak, Phecda, Megrez, Alioth and Mizar — are part of a cluster. Astronomers have tracked down over 30 other members of this cluster. They have also concluded we are inside it! The sun just happens to be within this scattered group of stars but nearby Sirius is a true member.

The cluster exists because the member stars all formed from the same cloud of dust and gas. That origin dates back not nearly as far as the birth of our own star. The common origin also means that the five related stars are traveling through space at approximately the same pace and in the same direction. As a group they are receding from us at about seven miles per second. Alkaid and Dubhe are also receding but both have another component of motion (known as *proper motion*) that is taking them in directions that will cause the break-up of the dipper configuration. But it is a process requiring thousands of years to disrupt the familiar grouping.

All the constellations are breaking apart as a result of star motion but it is an agonizingly slow process. If man is around a million years from now, all the sky patterns will be new. The old idea that the stars are holes in a giant celestial sphere (although wrong) is actually more descriptive of the unaided eye appearance of the sky.

Our study region this month includes the nearby small constellation Canes Venatici, a zone distinguished by only one moderately bright star. At magnitude 2.9, Cor Caroli is, however, brighter than Megrez in the Big Dipper. Cor Caroli and Alioth in the Dipper are the two brightest members of a rare class of variable stars known as magnetic spectrum variables. For reasons not yet fully understood, these stars have monstrous magnetic fields that oscillate their spectra. To the unaided eye or in the telescope, however, they look like ordinary stars.

Cor Caroli is a pretty double star in a small telescope but we chose not to discuss it below because it overlaps into another sky area to be examined in June. There are plenty of other exciting objects in this month's region whether you have a 2.4 inch refractor or major observatory at your disposal.

EYEPIECE IMPRESSIONS

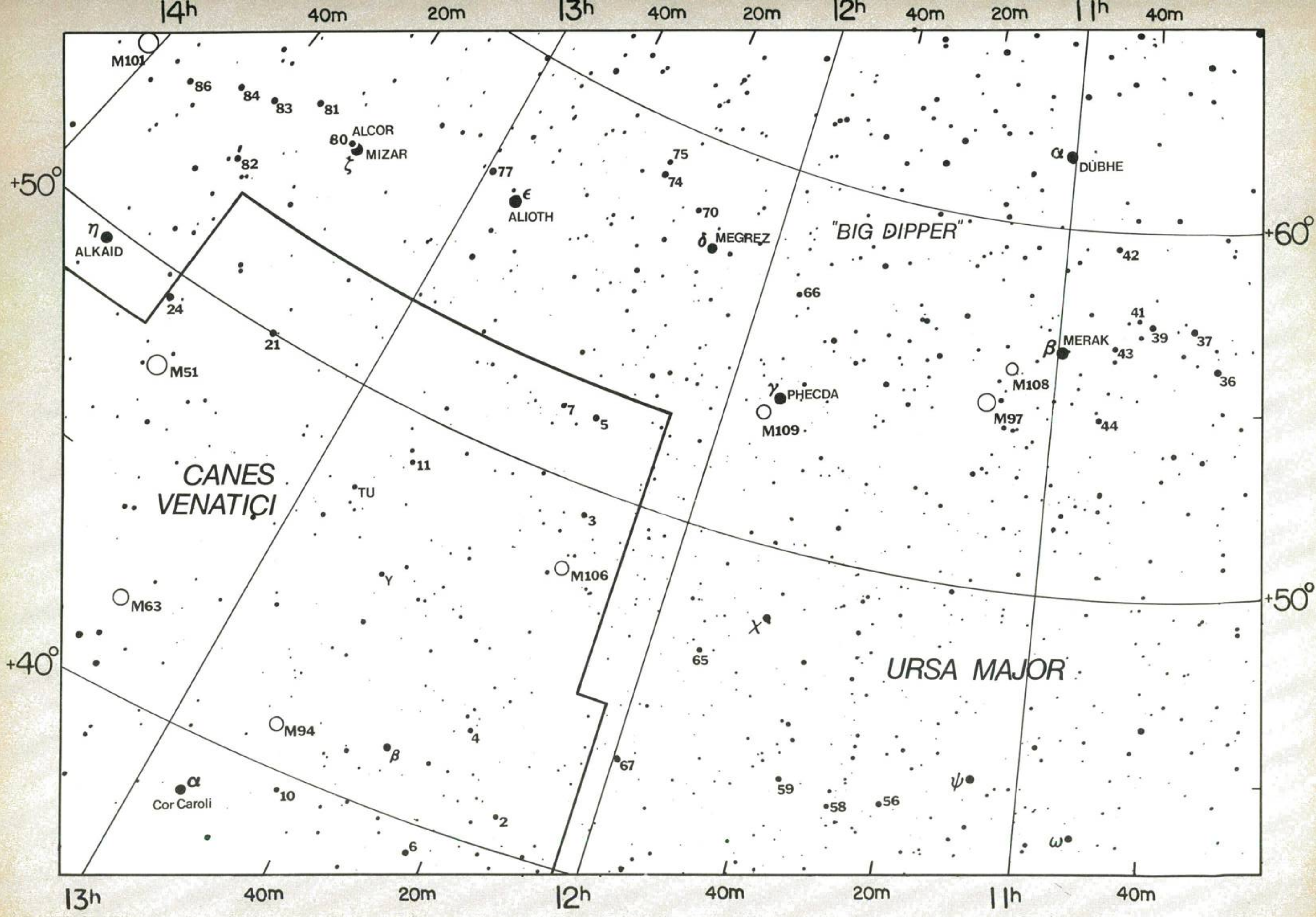
Mizar and Alcor

The sky in and about the Big Dipper, now high in the northeast, contains an adventureland of stellar and deep-sky treasures. Without question, the beautiful multiple sun system formed by Mizar and Alcor [Zeta (ζ) and 80 Ursae Majoris] at the "bend" in the Dipper's handle reigns supreme over this region and ranks as one of the showpieces of the heavens. A visual delight to beginner and veteran observer alike, this object seems like an old friend to which we can turn time and again for inspiration.

Second magnitude Mizar and fourth magnitude Alcor form an obvious naked eye pair, separated by some 12 minutes of arc on the sky (a little more than 1/3 the moon's apparent diameter). The combination is a fine sight in binoculars and finderscopes. Mentioned throughout recorded history, the Arabs long ago referred to Mizar as the "horse" and to Alcor as its "rider". The small star was regarded as a test of keen eyesight in times past, but is certainly no longer so today. Perhaps its brightness or separation from Mizar has increased over the centuries?

Webb in his classic **Celestial Objects for Common Telescopes** calls attention to the important fact that "...Mizar and Alcor form a pair to the naked eye, and thus become an excellent object for the beginner, as the telescopic increase of brightness and distance admits of direct comparison; but the inversion of the astronomical eyepiece must be borne in mind, or the identity will be perplexing."

In the field of a 2.4 or 3 inch refractor, this object is a sight never to be forgotten. As little as 30 power will easily resolve Mizar itself into two stars of magnitude 2.1 and 4.2 separated by 15 seconds of arc. Indeed, the rule for best results in viewing double and multiple stars is to employ the lowest magnification that will just resolve the components clearly. Many observers greatly reduce the impact of these objects by the use of too much power. Mizar's two dazzling suns and nearby Alcor combine to make a neat triple within the field of a low power eyepiece. All three appear brilliant white in hue, with perhaps a trace of blue or green.


14h
40m
20m
13h
40m
20m
12h
40m
20m
11h
40m
+50°
+60°
+50°
+40°
13h
40m
20m
12h
40m
20m
11h
40m
M101
86
84
83
81
80
ALCOR
ζ
MIZAR
82
77
ε
ALIOTH
75
74
70
δ
MEGREZ
"BIG DIPPER"
α
DUBHE
42
η
ALKAID
24
21
M51
66
41
39
37
β
MERAK
43
36
M108
γ
PHECDA
M109
M97
44
7
5
11
CANES
VENATICI
TU
3
M106
Y
M63
χ
65
URSA MAJOR
M94
4
β
67
α
Cor Caroli
10
59
58
56
ψ
2
6
ω

Located 88 light-years from us, this system is also of considerable interest historically. Mizar was the first double star discovered (by Riccioli in 1650), the first pair ever photographed (by Bond in 1857) and the first spectroscopic binary found (in 1889 by Pickering). Mizar A and B and Alcor are all double according to their spectra and thus form an amazing six star family with interacting orbits.

M-101

Forming a triangle with Mizar and Eta (η) — the star at the end of the Dipper's handle–this large face-on spiral galaxy can be picked up in three and four inch telescopes at 45 power with careful sweeping on dark nights. Although of magnitude 9.6, this distant pinwheel of stars is spread over an area more than 2/3 the moon's diameter, making its actual surface brightness quite low. As a result, many observers pass right over M-101 while scanning back and forth across its place in the sky. The slightest trace of haze or bright moonlight will blot out its existence, as will dew on the optics — especially the eyepiece.

Large amateur instruments will reveal traces of the spiral structure within the circular glow under good conditions. Several bright supernovae have been discovered within this galaxy in the past and a patrol of M-101 for possible additional outbreaks makes a good project for experienced observers having 10 and 12 inch reflectors. A detailed sketch at the telescope of all visible stars in and near the galaxy should be made, and then carefully compared to its appearance each clear night. Other spiral galaxies might also be monitored. The anticipation of "something happening out there" will add greatly to the enjoyment of observing these other universes scattered across space and time.

M-51

The region beneath the Big Dipper's handle is rich in galaxies of every description but the outstanding attraction of this area is the famous Whirlpool nebula (M-51). Situated at the apex of a triangle formed by Eta (η) Ursae Majoris and 24 Canum Venaticorum, this broadside spiral can be glimpsed with a 2.4 inch refractor at 30 power.

One of the most often pictured objects of its class, the Whirlpool was the first galaxy in which spiral structure was recognized. The discovery was made in 1845 by William Parsons, a wealthy British amateur astronomer using his home built 72 inch reflector. That backyard monster, although long ago dismantled, is the largest telescope ever built and used by an amateur astronomer.

Surprisingly, the spiral features of M-51 can be seen in 8 and 10 inch reflectors today and have even been glimpsed in a six inch telescope under excellent sky conditions. This is a good illustration of William Herschel's dictum: "When an object is once discovered by a superior power, an inferior one will suffice to see it afterwards." In other words, once the existence of something is

Ⓐ

On an exceptionally clear night it is possible for an experienced observer to detect the spiral structure of M-51 with a moderate sized telescope. This is an eight inch Newtonian reflector view at 120 power giving a field of view 15 minutes of arc across.

Ⓑ

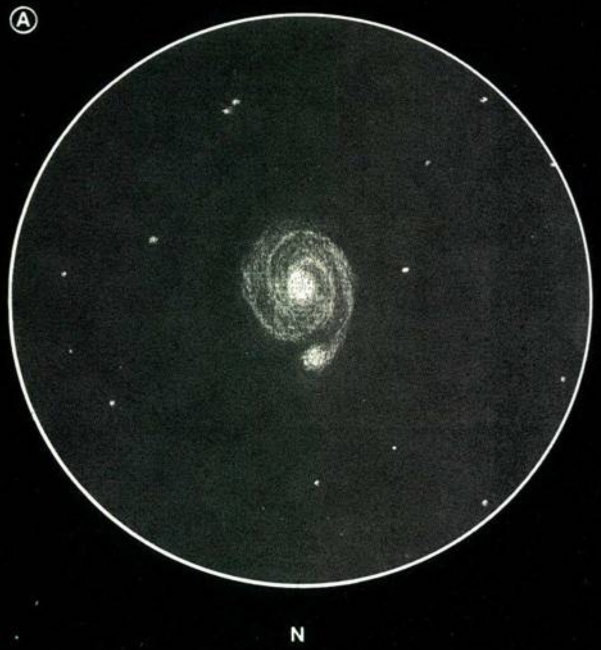
Mizar, the star at the "bend" in the Big Dipper's handle, is a beautiful double star in a small telescope. This view at 45 power through a four inch reflector is one degree across — wide enough to easily include Alcor, the naked eye companion to Mizar.

Ⓒ

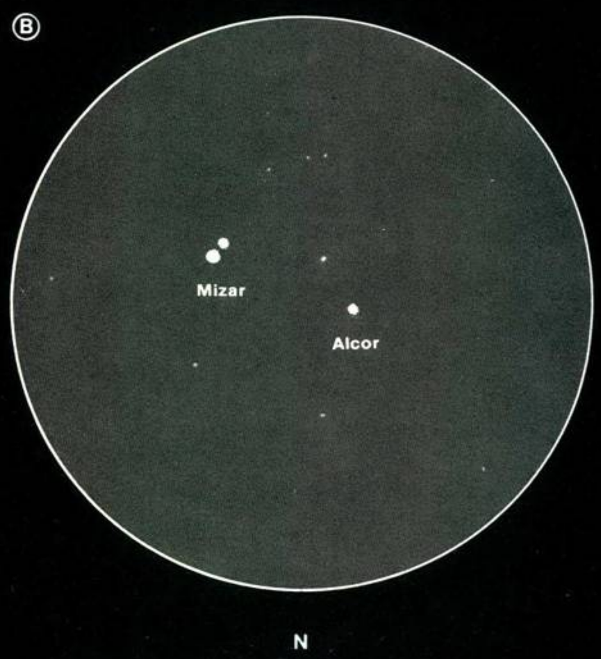
The pale and ghostly Owl nebula (M-97) can be detected with moderate sized telescopes. However, the Owl's "eyes" and other subtle features of this planetary nebula are at the threshold of an eight inch telescope. This view at 160 power through a 10 inch reflector is about 15 minutes of arc wide.

Sketches by James Mullaney

Ⓐ



Ⓑ



known, a smaller telescope will show it because the observer knows exactly what he is looking for. The moons of Mars offer another example of this interesting principle.

M-51 (NGC-5194) is unique among bright galaxies in that it has a bright close companion (NGC-5195) — giving the impression of a double object in small telescopes. The main body of M-51 is noticeably elliptical in outline (5 by 10 minutes of arc), and at magnitude 8.1 is one of the brightest galaxies in the sky. Its small satellite is only two minutes in diameter and somewhat fainter at magnitude 8.4. The two objects appear connected by a bridge of faint luminosity — one of the spiral arms — which has been glimpsed in a six inch reflector.

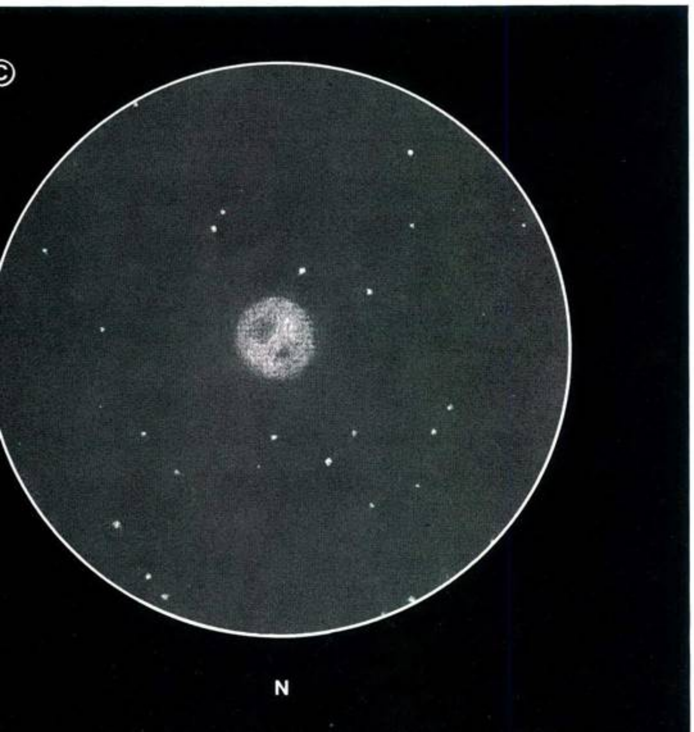
In addition to good transparency (atmospheric clarity), good seeing (image steadiness) is also necessary for viewing the structure of the Whirlpool. In those rare moments of tranquil air on dark nights, an 8 or 10 inch reflector at medium powers will reveal the uniform glow of M-51 suddenly breaking up into tantalizing fragments of spiral arms and dark dust lanes, coiling outward from the central nucleus.

In **1001 Celestial Wonders**, Barns refers to the Whirlpool as "Transcendent... resembling more an eternal question-mark — a supernal celestial enigma which in very truth it is." Half a century later, these words still apply embodying our meager knowledge of the mysterious forces at work within this and other such galaxies. Lying at a distance of 12,000,000 light-years from us, M-51 has been one of the most intensively studied objects of its class.

Y Canum Venaticorum

To the east and south of the Whirlpool galaxy is a fiery pulsating beacon — a celestial stoplight — just visible to the unaided eye most of the time. A finder pointed 1/3 of the way from Beta (β) Canum Venaticorum to Mizar will show Y shining in isolated splendor amidst a stellar desert. One of the brightest representatives of spectral class N, this irregular variable star ranges from 5.2 to 6.6 magnitude in a rough period of 158 days. Thus it is always available for viewing in even the smallest of instruments.

Y's remarkable reddish-orange hue is stunning in a four inch reflector at 45 power, and larger reflectors with their superior color rendition over refractors give truly spectacular views of this object. A slight defocusing of the image (preferably outside rather than inside of focus) often makes star colors more obvious, especially to the beginning observer or visitors at the telescope whose eyes have yet to be trained for color perception.



M-97

Another frequently pictured celestial personality — and one of the most difficult for small telescope users — is found just two degrees southeast of Beta in the Big Dipper's bowl. This is the well-known Owl nebula (M-97). Having only the brightness of a 12th magnitude star, this feeble light is spread over an area of some three minutes of arc in extent — making the Owl a real challenge to pick out from the sky background under typical city observing conditions. M-97 is quite large as planetary nebulae go, being nearly three times the apparent size of the famous Ring nebula in Lyra.

While searching for this elusive object you may accidentally happen upon an elongated patch of light known as M-108, situated roughly midway between the Owl and Beta. This 11th magnitude galaxy is often mistaken for M-97 itself. However, its eight by one minute dimensions make it unmistakably elongated, whereas its neighbor is circular.

Though difficult, both objects can be seen in a 2.4 inch refractor at 30 power and present interesting sights in six inch and larger telescopes. In searching for this duo — as with all faint extended nebulosities — a well dark-adapted eye and the use of averted (side) vision are essential for success.

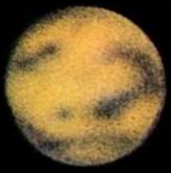
The Owl appears featureless in most amateur scopes, but two dark areas or "eyes" can be glimpsed within the pale disc in 10 and 12 inch reflectors at medium to high magnifications. These were first noticed by William Parsons who gave this and many other well-known deep-sky objects (including the Whirlpool nebula) their imaginative names.

A long forgotten note by Webb mentions that before 1850 there was a star visible in both "eyes", but since then only one has been seen. Other planetaries are on record in which associated stars have changed in brightness and perhaps the missing star will reappear someday. At present this wise old celestial owl seems to be keeping watch on us with one eye open and one closed.

Planet Finder

Ⓒ Cer

April	1	15
R.A.	1^h11^m	1^h3
Dec.	+0°03'	+2°
Mag.	+8.6	+8.6



Ⓐ Mercury

April	1
R.A.	23^h47^m
Dec.	-3°52'
Mag.	-0.8

Ⓑ Mercury

April	15
R.A.	1^h23^m
Dec.	+7°41'
Mag.	-1.7

Ⓜ Mars

April	1	15
R.A.	21^h41^m	22^h22^m
Dec.	-15°10'	-11°36'
Mag.	+1.3	+1.2

Ⓝ Neptu

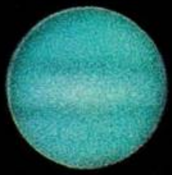
April	15
R.A.	16^h4
Dec.	-20°3
Mag.	+7.7

SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

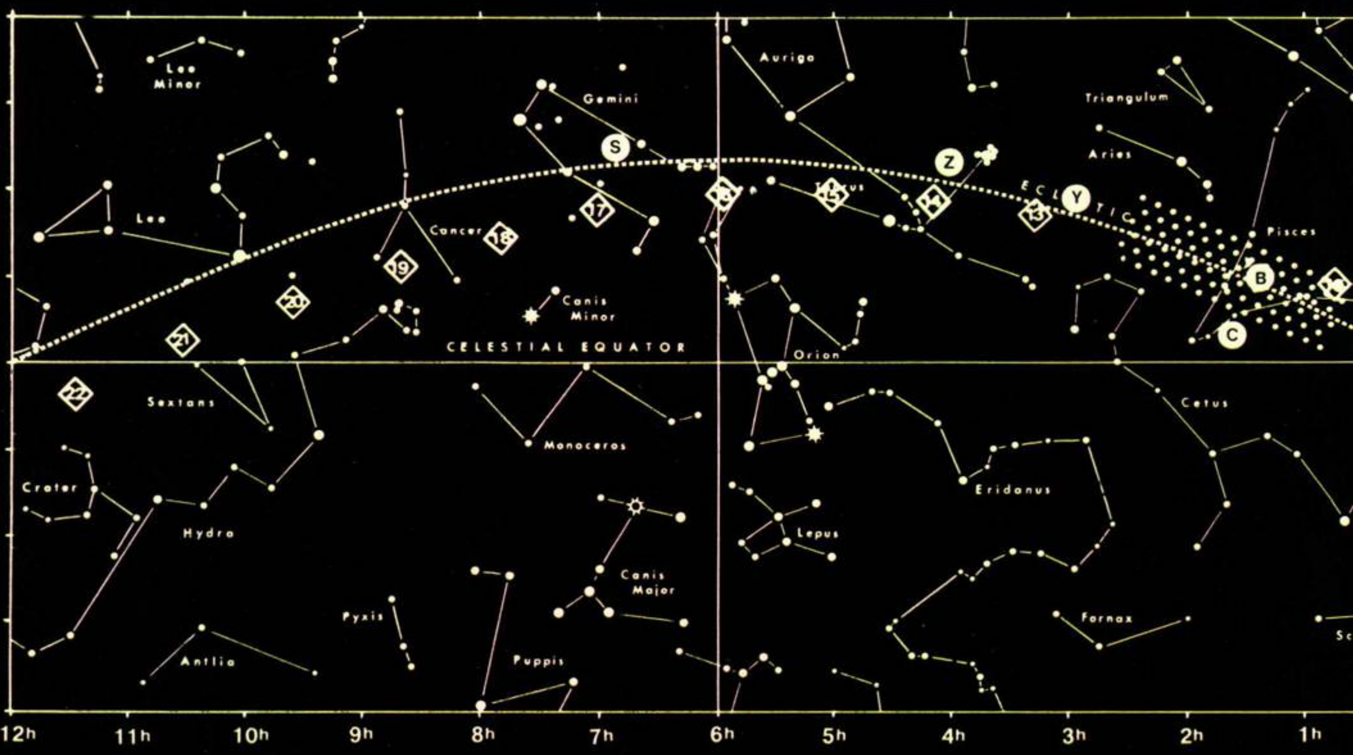
Ⓢ Saturn

April	1	15
R.A.	6^h53^m	6^h56^m
Dec.	+22°39'	+22°38'
Mag.	+0.3	+0.3



Ⓤ Uranus

April	15
R.A.	13^h55^m
Dec.	-11°10'
Mag.	+5.7


Leo Minor
Leo
Gemini
S
Cancer
16
17
18
19
20
21
22
Canis Minor
CELESTIAL EQUATOR
Sextans
Crater
Hydra
Monoceros
Canis Major
Pyxis
Antlia
Puppis
Auriga
Orion
Lepus
Eridanus
Z
Y
ECLIPTIC
Triangulum
Aries
Pisces
B
C
Cetus
Fornax
Sc
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

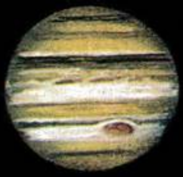
Map by Raymond G. Coutchie

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

April 1975

Ⓥ Vesta

April	1	15
R.A.	21^h52^m	22^h18^m
Dec.	-15°13'	-13°26'
Mag.	+7.4	+7.4



Ⓙ Jupiter

April	1	15
R.A.	0^h14^m	0^h23^m
Dec.	+0°26'	+1°41'
Mag.	-1.6	-1.6

Ⓨ Venus

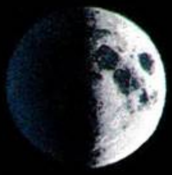
April	1
R.A.	2^h41^m
Dec.	+17°12'
Mag.	-3.5

Ⓩ Venus

April	15
R.A.	4^h00^m
Dec.	+22°01'
Mag.	-3.5

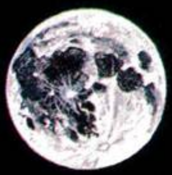
Ⓟ Pluto

April	15
R.A.	12^h53^m
Dec.	+13°06'
Mag.	+14



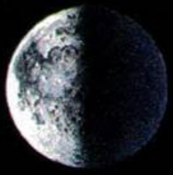
First Quarter

April 18



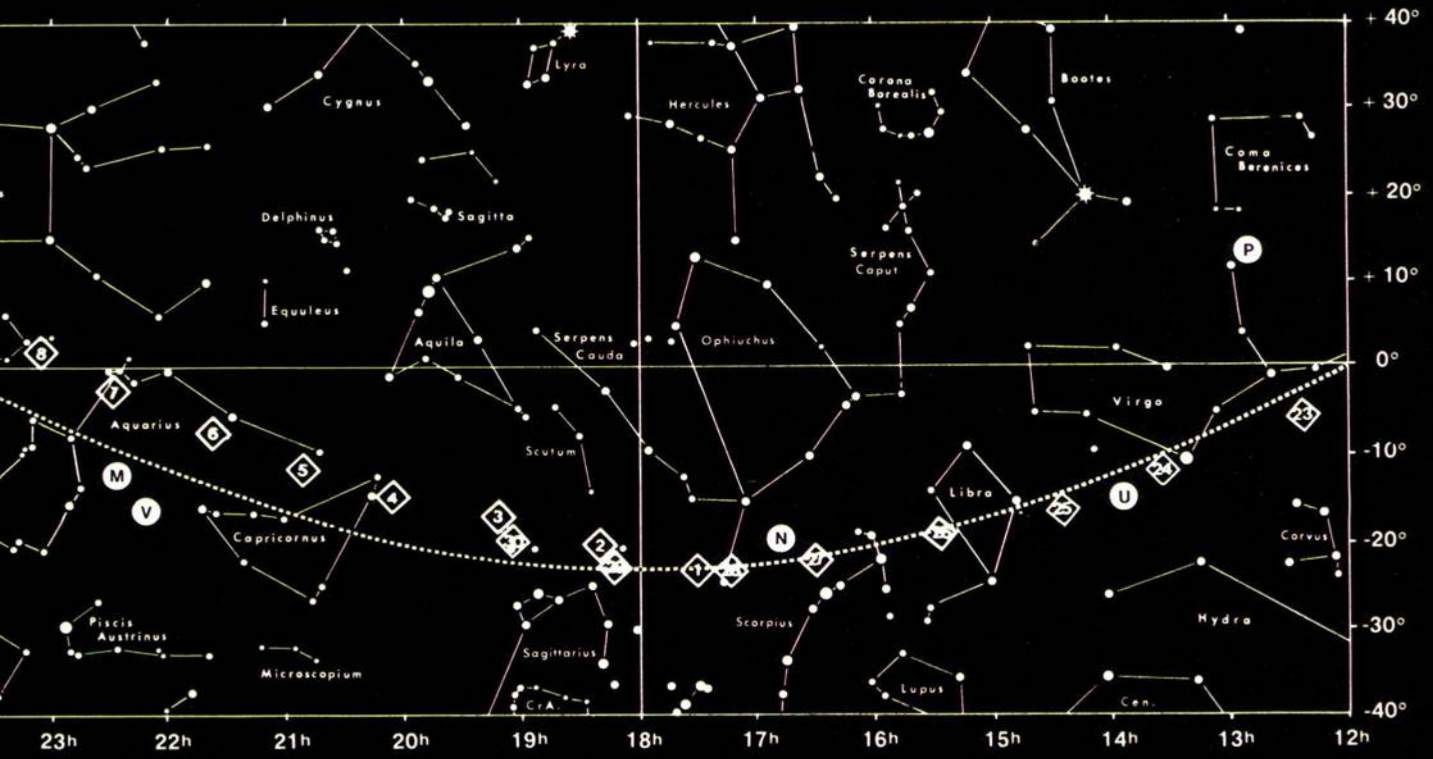
Full Moon

April 25



Last Quarter

April 3



+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Serpens Caput
Equuleus
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Libra
Capricornus
Scorpius
Corvus
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA
Cen.
M
V
N
U
P

Artwork by Victor Costanzo

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.

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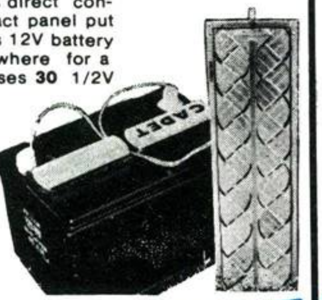

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This staunch leader of the Dynascope line has won widespread recognition from schools, colleges, and professionals, as an outstanding achievement in a 6-inch telescope. Since it was introduced a few years ago, our files have become filled with complimentary letters from excited amateurs and professionals all over the country. Each one is truly amazed at the superior optical performance of this RV-6 6-inch Dynascope! Here is large aperture in a quality instrument at a price that compares with many 4-inch telescopes. *And this low cost includes such exclusive extra features as electric drive* (patented), *setting circles, and rotating tube!* There are no "extras" to run up your cost!

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Only Criterion's engineering ingenuity, coupled with volume production and modern manufacturing methods, makes this handsome 6-inch model available at such reasonable cost. You can order it with complete confidence that it will live up to your expectations in every way, for this assurance is *guaranteed* under our full-refund warranty. Send your check or money order today. Or use our liberal time-payment plan and take months to pay.

You Could Pay $100 More Without Getting All These Superior Features (Except on Another Dynascope)

1. **EXQUISITE OPTICAL SYSTEM INCLUDES f/8 6-INCH PARABOLIC MIRROR** made of **PYREX**-brand glass, accurate to better than 1/8 wave, zircon-quartz coated, and guaranteed to reach the theoretical limits of resolution and definition. Teamed with elliptical diagonal mounted in 4-vane adjustable spider.
2. **NEW DYN-O-MATIC ELECTRIC DRIVE** with smooth self-acting clutch that engages and disengages automatically as you seek different objects. Will not interfere when manual operation is desired. Safety housed case. Plugs into ordinary AC socket.
3. **TWO EYEPIECES:** Achromatic Ramsdens **70X** (18 mm.), **140X** (9 mm.). Also available: **100X** (12.7 mm.), **180X** (7 mm.). Achromatic Ramsdens, $14.95 each; **220X** (6 mm.), **320X** (4 mm.). Orthoscopics, $18.50 each.
4. **SOLID NEW EQUATORIAL MOUNT,** extra-reinforced design to provide pillarlike stability. No annoying side play or wobble. Adjusts easily to any latitude.
5. **SETTING CIRCLES** for both right ascension and declination. Handsomely engraved and finished in fine aluminum.
6. **6 x 30 FINDERSCOPE, ACHROMATIC, COATED,** with accurate cross hairs and fine focus. Durable cast-aluminum bracket with 6 adjusting screws allows positive collimation.
7. **ROTATING TUBE FOR MAXIMUM VERSATILITY AND VIEWING COMFORT.** Solid-cast chrome-finished rings are generous 1" wide with felt lining. Newly designed construction, with oversized knurled adjusting knobs, affords maximum rigidity and allows quick disassembly and portability, with or without tube.
8. **STRIKINGLY HANDSOME WHITE 50" BAKELITE TUBE** with porcelainized Duralite finish, durable yet light. Walls are 1/8" thick, completely insulated and anti-reflective blackened inside.
9. **BRASS RACK-AND-PINION EYEPIECE HOLDER** has precision-cut rack and gear for easier, smoother, more positive focusing. Takes standard 1¼" oculars, negative or positive.
10. **STRONG, VIBRATION-FREE, ALL-METAL TRIPOD** with easily removable legs. Provides sure, steady support, plus lightweight portability.

Criterion Manufacturing Co.

620 Oakwood Ave., West Hartford, Conn. 06110

Manufacturers of Quality Optical Instruments

Orders for the RV-6 Have Set New Records!

Demand for this fine instrument, so well proved in use, has been soaring, as more and more serious telescope buyers have come to realize, by comparison, what an extraordinary value it is. To keep pace, we hurried along a planned expansion into facilities more than three times as large as before.

We stepped up production as rapidly as we could—but remember, this is a precision, handcrafted instrument, individually built to our exacting standards, and individually guaranteed. In addition, our industry like most others has had to contend with shortages. At times, critical materials have just not been available. In spite of all efforts, order backlogs grew, and we have felt obliged to offer refunds to anyone who did not want to wait. (Very few accepted—which itself is significant.) Today our backlog has been brought down a great deal, though we must still reluctantly keep you waiting a while. Our apologies...but it is comforting to know that when your telescope arrives, it will be in every respect the easy-to-operate, outstanding performer you ordered—an RV-6 Dynascope.

Criterion Manufacturing Co. Dept. AS-29
620 Oakwood Ave., West Hartford, Conn. 06110

☐ Please send me, under your unconditional guarantee, the RV-6 6-inch Dynascope. Payment of $229.95 plus $15.00 crating charge is enclosed.

☐ Send FREE ILLUSTRATED LITERATURE describing the RV-6 6-inch Dynascope and all the telescopes in the Dynascope line.

☐ Send FREE ILLUSTRATED LITERATURE on your new DYNA-TRACKER™ Variable-Speed Control for RV-6 or other electric-drive telescopes.

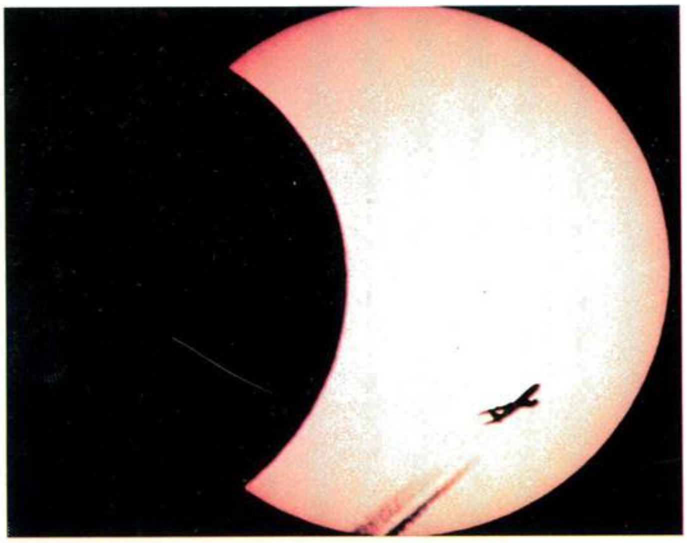
Name ____________________

Address ____________________

City ____________ State ____________ Zip ____________

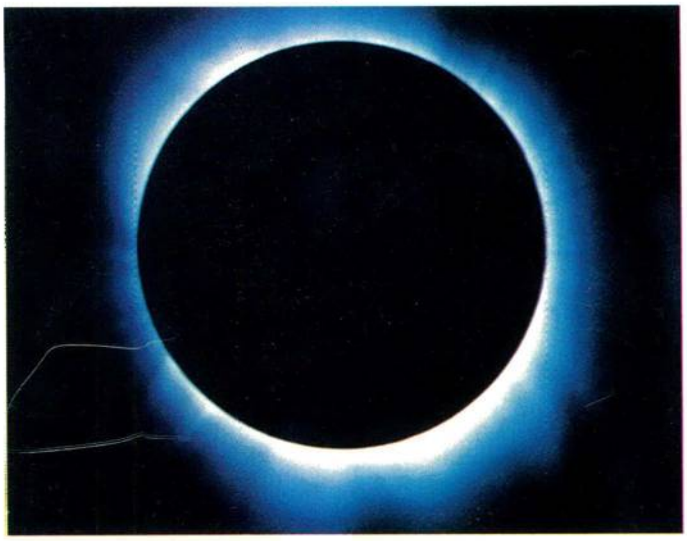
Celestron®

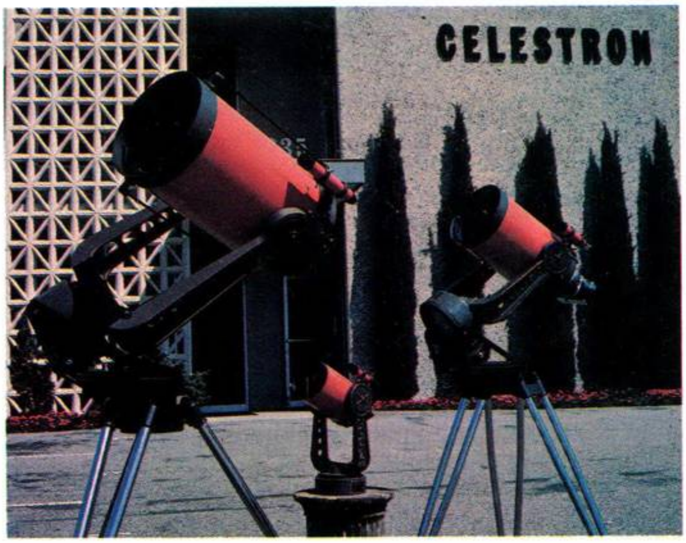
World's Leading Manufacturer of Schmidt-Cassegrain Optics for Astronomy, Industry, Education



Above: Contrails swirl behind a jet crossing the partially eclipsed solar disk — Celestron 8 photo.

Below: A crown of light rings the sun in total eclipse — Celestron 5 photo.





World's only complete line of large-aperture, compact-portable telescopes: the prestigious Celestron 14 (left), the super-portable Celestron 5 (center), and the most popular of the Celestron telescopes, the Celestron 8.

Nature Waits for No Man

As far as Nature is concerned, her comets arrive on schedule. Her supernovae blaze up at exactly the right moment. Her lunar and solar eclipses come and go precisely on time.

Unfortunately, however, Nature's timetable is often a secret. No one knows when a supernova will flare up and outshine the star of Bethlehem. No one knows when the lunar crater Aristarchus will start to glow again, or for how long.

And consider this: Halley's Comet is due back in 1986. But suppose it arrives early? Impossible? Perhaps.

Even when Nature's schedule is known, news of celestial events seldom reaches you in time to order and receive a telescope. If you wait until the event is popularized, you won't get your telescope in time.

When Halley's Comet reappears, a flood of stories will be carried in the press and over the air waves. But by then a two-year backlog among telescope manufacturers won't be uncommon.

So why not be ready now? Order your Celestron while a slow period for the economy (and cosmic spectaculars) presents you with an opportunity to purchase at an unprecedented price.

Celestron 5 - $695
(reduced from $750)

LIMITED OFFER

Celestron 8 - $79
(reduced from $965)

"First-Come, First-Served . . . Offer Expires May 31, 1975"

The telescope that has come to be accepted as the number one choice the world over . . . the most coveted, most recommended among serious amateur astronomers, professors of astronomy and planetarium educators, is now available to you at a drastically reduced price for a limited time only.

Since the introduction of the Celestron 8 and the Celestron 5 some years ago, the demand for these fine instruments has always exceeded our production capacity. Each year, orders have typically doubled from the preceding year.

To meet this increased demand, it has been necessary to acquire new manufacturing space, place additional machinery in operation and train new personnel.

Moreover, to keep our delivery times short (we seldom ask our customers to wait more than eight weeks for these telescopes), it has been necessary to predict orders six months in advance. This has required applying a major portion of our working capital toward financing an in-process inventory of telescopes.

Now, because of the economy, orders have leveled off temporarily and we have, nearing completion, a number of Celestron 5 and Celestron 8 telescopes which were begun in anticipation of a continually rising level of orders.

To reconvert this inventory into working capital, we have decided to forego profit on these instruments and offer them at a reduced rate. These telescopes are available on a first-come, first-served basis.

C5, C8 owners: If you haven't received your copy of our new instruction manual, drop us a postcard. No charge, of course.

Celestron Pacific

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